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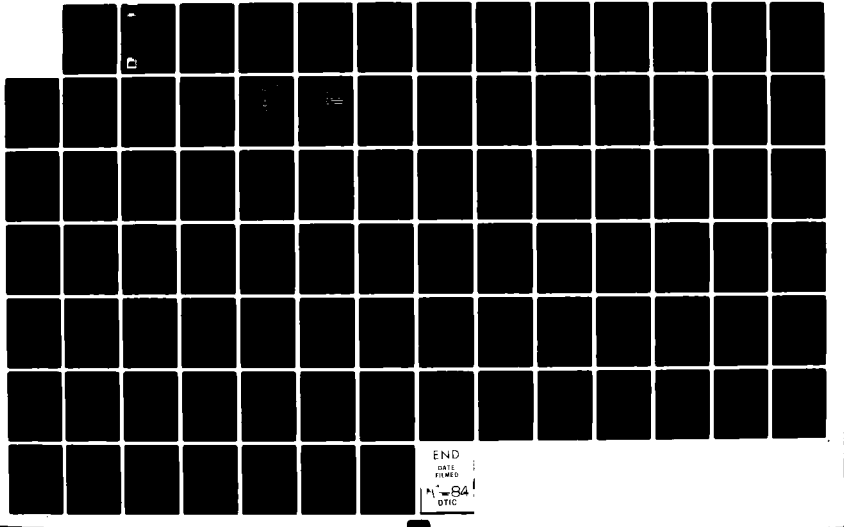

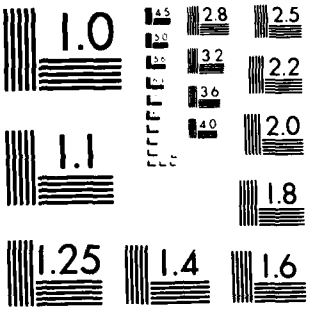

COMPUTER-AIDED ANALYSIS OF CONCRETE STRENGTH TEST RESULTS

by

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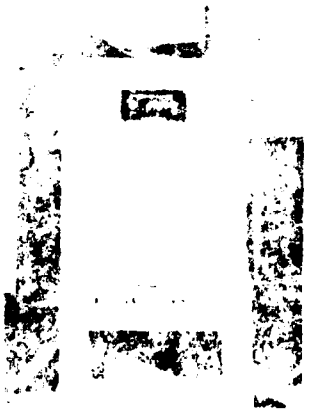

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Concrete	Strength test
Cylinder test	Test results
Predicted strength	Unconfined compression

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report documents a computer-aided statistical analysis program that is primarily designed to (1) process laboratory strength test results and generate regression data for accelerated versus design-age strengths and (2) process field strength test results using laboratory regression data and generate predicted design-age and required average strengths in accordance with EM 1110-2-2000, "Standard Practice for Concrete." The statistical portions of the

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20. ABSTRACT (Continued)

program were written to comply with "Recommended Practice for Evaluation of Strength Test Results of Concrete, ACI 214-77" and "Use of Accelerated Strength Testing, ACI 214.1R-81."

The program is an interactive time-sharing program written in Honeywell Level 66 Fortran language. The program is accessible through the CORPS Computer Library System as program X0064. A graphics terminal such as the Tektronic 4014 is required to take full advantage of the capabilities of the program. Output data are presented in tabular or graph form or both.

PREFACE

This report was prepared at the Structures Laboratory (SL) of the U. S. Army Engineer Waterways Experiment Station (WES) under the sponsorship of the Headquarters, U. S. Army Corps of Engineers (HQ USACE) as a part of Civil Works Investigation Studies Work Unit 31138, "New Technologies for Testing and Evaluating Concrete." Mr. Joseph L. Lamond and Mr. Fred Anderson (DAEN-CWE-DC) served as HQ USACE Technical Monitors.

The study was conducted under the general supervision of Mr. Bryant Mather, Chief, SL, and Mr. John Scanlon, Chief, Concrete Technology Division (CTD), SL; and under the direct supervision of Mr. Kenneth L. Saucier, Chief, Concrete and Grout Group, CTD, Mr. James E. McDonald, and Mr. Henry T. Thornton, Acting Chief, Evaluation and Monitoring Group, CTD. This report was prepared by Mr. Roy L. Campbell, Sr.

The Commander and Director of WES during this study and the preparation and publication of this report was COL Tilford C. Creel, CE. Mr. F. R. Brown was Technical Director.

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CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
inches	2.540	centimetres
pounds (force) per square inch (psi)	6.894757	kilopascals
Fahrenheit degrees	5/9	Celsius degrees or Kelvins*

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvins (K) readings, use: $K = (5/9)(F - 32) + 273.15$.

COMPUTER-AIDED ANALYSIS OF CONCRETE STRENGTH TEST RESULTS

PART I: INTRODUCTION

1. This report contains the basic information needed by a user to execute a computer program called "CONEVAL." The program provides computer-aided statistical analysis and report-form output of concrete strength test specimen results. The program is primarily designed to (a) process laboratory test results and generate regression data for accelerated versus design-age strengths and (b) process field strength test results using laboratory regression data and generate predicted design-age and required average strengths. The statistical portions of this program are written to comply with ACI 214-77 and ACI 214.1R-81. The program is accessible through the CORPS Computer Library System as program X0064.

2. In retrospect, the concrete specimens should be made according to ASTM Designations: C 31-69 and C 192-81 or according to C 684-81 for accelerated testing and tested in accordance with ASTM: C 39-81.

PART II: PROGRAM FEATURES

Features Applicable to Analysis of Both Laboratory and Field Data

3. The program is written for time-sharing system use and is interactively executed. A restart option is available that allows the user to process up to 480 concrete test samples. The user has the option to display or not to display input and output values in either tabular or graph form or both. The displayed tables and graphs can be automatically copied by the program. Graphs can be redisplayed using scales selected by user.

Features Applicable to Analysis of Laboratory Data

4. For analysis of laboratory strength test results, the program performs a linear regression for accelerated versus design-age strengths. The series of individual points that are graphically displayed with the regression curve are selected by the user. At this point in the program, the selection of points and the replotting of the graph can be repeated as many times as needed. Field data can be processed as laboratory data to generate a regression curve by simply giving a 'N' response for the field analysis query.

Features Applicable to Analysis of Field Data

5. For analysis of field strength test results, strength data are processed according to age of test specimen at time of testing. The program uses interactively entered laboratory regression data (slope, Y-intercept, number of points on curve, and 95 percent confidence interval) to generate predicted strengths for design-age group and required average strengths for both accelerated and design-age groups. The program computes averages of the sample input. It statistically analyzes the strength test results for standard deviations, coefficients of variation,

and ranges. The test-age group(s) for which data are to be displayed is selected by user.

6. For structural concrete an average of the last three consecutives tests is maintained by the program while for nonstructural concrete an average of the last five tests is maintained. The program flags design-age strengths for structural concrete in which (a) the average of a set of three consecutive tests is less than the specified strength, f'_c, (ACI 318-77, para 4.8.2.3(a)) and (b) an individual test is more than 500 psi below f'_c (ACI 318-77, para 4.8.2.3(b)). This procedure will allow calculations to be made to determine compliance with the provisions of Section 7-2.e. of EM 1110-2-2000.

PART III: DEVICE

7. A graphics terminal* is required to take full advantage of the capabilities of this program. For a user who only has access to a line-printer terminal,** tables can be listed by giving the following question responses:

a. Entering 'ALP' for device.

b. '0' (zero) for number of copies.

c. A carriage return at the end of each table.

d. Entering 'N' for the plot option.

---

* For example, the Tektronix 4014.

** For example, Texas Instruments Silent 700.

PART IV: INPUT

Units

8. Input units are selected and interactively entered into the program by the user. Units can be either non-SI or SI (metric). Units most compatible with output formats are (a) inches (in.), Fahrenheit degrees (F), and pounds per square inch (psi) or (b) centimetres (cm), Celsius degrees (C) or Kelvins (K), and kilopascals (kPa).

Format

9. Alpha data are read by the program using an A30 character format. Numeric data are read using a free-field format. The order of values contained in a file of either laboratory or field data is the same, except that the design water:cement ratio is not included with the laboratory data. The input file containing either laboratory or field data is structured in either initial or restart file forms. The order and description of values contained in the initial and restart file forms are presented in Figure 1.

Initial File

10. An initial file is used to start the analysis. It can contain up to 60 samples with a maximum of 7 tests per sample and 2 tests per age group. Note that in order to comply with the provisions of Section 7-2.e.(3) of EM 1110-2-2000 each sample should consist of two tests each for both the accelerated and design-age groups and one test for each informational age group. The number of tests per sample and the number of tests for a given age group are constants for the analysis. The order and description of values contained in an initial file are defined by lines identified as 1 through 6 and 7 through 9 in Figure 1. An example of an initial file is presented in Figure 2.

```
INPUT
-----

LINE 1:  LINE NO.,NO. TESTS VALUES PER LINE INPUT(MAX. 7)
LINE 2:  LINE NO.,TEST AGES(MAX. 7)
LINE 3:  LINE NO.,PROJECT NAME(A45)
LINE 4:  LINE NO.,CONTRACT NUMBER(A45)
LINE 5:  LINE NO.,MIX INDENTIFIER(A45)
LINE 6:  LINE NO,DESIGN AGE,DESIGN STRENGTH,T-DISTRIBUTION FACTOR,
         MAXIMUM SIZE AGGREGATE AND DESIGN WATER-CEMENT RATIO<

**********************************************************************
  *LINES 6A THRU 6H FOR RESTART FILE ONLY
   LINE 6A: LINE NO.,NO. WATER-CEMENT RATIOS,CUMULATIVE SUM OF
            WATER-CEMENT RATIOS,NO. SLUMPS,CUMULATIVE SUM OF
            SLUMP,NO. AIR CONTENTS,CUMULATIVE SUM OF AIR CONTENTS
  *REPEAT LINES 6B AND 6C FOR EACH SET OF 2-CYLINDER DATA
   LINE 6B: LINE NO.,NO. RANGES,CUMULATIVE SUM OF RANGES
   LINE 6C: LINE NO.,LAST 10 RANGE VALUES
  *REPEAT LINE 6D FOR EACH AGE GROUP ENTERED
   LINE 6D: LINE NO.,NO. TEST,CUMULATIVE SUM OF TEST VALUES,
            CUMULATIVE SUM OF SQUARES OF TEST VALUES,LAST 3 TESTS
            FOR STRUCTURAL CONCRETE OR LAST 5 TEST FOR NONSTRUCTURAL
            CONCRETE
   LINE 6E: LINE NO.,MINIMUM WATER-CEMENT RATIO,MAXIMUM
            WATER-CEMENT RATIO,PAIR OF MINIMUM AND MAXIMUM
            STRENGTH VALUES FOR EACH AGE GROUP
   LINE 6F: LINE NO.,NO. REGRESSION POINTS,SUM OF ACCELERATED
            STRENGTHS,SUM OF SQUARES OF ACCELERATED STRENGTHS
   LINE 6G: LINE NO.,SUM OF DESIGN-AGE STRENGTHS,SUM OF SQUARES
            OF DESIGN-AGE STRENGTHS,SUM OF PRODUCT OF ACCELERATED
            AND DESIGN-AGE STRENGTHS
   LINE 6H: LINE NO.,PAIRS OF ACCELERATED AND DESIGN-AGE STRENGTHS
```

Figure 1. Order and description of input data (Sheet 1 of 2)

```
**************************************************************************
    *REPEAT LINE 7 FOR EACH SAMPLE(MAX. 60)
     LINE 7 : LINE NO.,YEAR(I2)$,MONTH(I2)$,DAY(I2)$,SAMPLE
              IDENTIFIER(A8)$,WATER-CEMENT RATIO,SLUMP,AIR CONTENT
              AIR TEMPERATURE,CONCRETE TEMPERATURE,STRENGTH VALUES
              ORDERED BY AGE,REMARKS(A35)$


     < ENTER FOR FIELD ANALYSIS ONLY
     $ OUTPUT FIELD LIMITS
```


Figure 1. (Sheet 2 of 2)

```
1         7
2           1    1    7   28   90   90  365
3     RICHARD B RUSSELL
4     DACW78-81-C0084
5     TOY12
6           90      2000.       1.282        6.00        0.67
10 79   3 19  1          0.30  2.00  6.5 -100.   67.   265.   289.   495.   999.  1786.  1786.      0. G-02-23A
11 79   4 10 55          0.65  2.75  7.0 -100.   53.   265.     0.   796.  2036.  3348.  3289.      0. G-04-23C
12 79   4 17 68          0.    2.50  4.8 -100.   54.   320.   325.   770.  2336.  4067.  3749.      0. G-02-23A
13 79   4 18 76          0.    2.25  5.8 -100.   45.   301.   308.   893.  2290.  3837.  3944.      0. G-02-23A
14 79   4 19 99          0.    2.25  4.8 -100.   54.   354.   318.   858.  2325.  3578.  3855.      0. G-06-24
15 79   4 19 107         0.    1.00  4.0 -100.   50.   371.   389.   831.  2341.  3767.     0.      0. G-06-24
16 79   4 20 115         0.    1.50  4.0 -100.   55.   361.   364.   833.  2414.  3979.  3873.      0. G-06-24
17 79   4 30 146         0.    2.00  7.0 -100.   49.   347.   354.   879.  1760.  3185.  3201.      0. G-04-22
18 79   5  1 154         0.    2.50  5.1 -100.   53.   622.   682.  1478.  3334.  6028.  4863.      0. G-04-22
19 79   5  2 178         0.    2.25  5.4 -100.   50.   637.   633.  1821.  2741.  4103.  3926.      0. G-02-22
20 79   5  4 202         0.    2.00  4.6 -100.   54.   376.   376.  1008.  2538.  4262.  4421.      0. G-06-22
21 79   5 14 227         0.    2.00  4.4 -100.   55.   573.   608.  1309.  3537.  6536.  5368.      0. G-03-23
22 79   5 16 242         0.    3.00  4.9 -100.   46.   424.   436.  1061.  2688.  3678.  4403.      0. G-04-21
23 79   5 18 250         0.    2.00  5.7 -100.   49.   516.   546.  1088.  3033.  4589.  4421.      0. G-04-21
24 79   5 18 274         0.    2.25  7.0 -100. -100.   474.   588.  1185.  2818.  4280.  4421.      0. G-02-21
25 79   5 18 282         0.    1.75  6.8 -100.   55.   477.   483.  1081.  2706.  4244.  4156.      0. G-02-21
26 79   5 19 298         0.    1.25  4.2 -100.   50.   584.   581.  1114.  2900.  4281.  4527.      0. G-03-23
27 79   5 23 332         0.    3.00  7.2 -100.   53.   521.   541.  1086.  2370.  3961.  3784.      0. G-06-22
28 79   5 23 340         0.    2.00  4.4 -100.   50.   520.   582.   958.  2440.  3749.  3808.      0. G-06-21
29 79   5 25 364         0.    1.50  5.4 -100.   48.   424.   416.  1819.  2885.  3944.  3767.      0. G-05-24
30 79   5 29 372         0.    2.75  5.0 -100.   48.   417.   427.  1008.  2704.  3767.  3979.      0. G-04-20
31 79   5 30 380         0.    1.50  5.4 -100.   50.   531.   534.  1486.  3484.  5258.  4969.      0. G-04-20
32 79   6  6 458         0.    1.75  5.2 -100.   50.   371.   382.  1088.  2706.  3808.  4509.      0. G-03-22
33 79   6  6 466         0.    3.00  7.0 -100. -100.   340.   350.   716.  1582.  2759.  2971.      0. G-03-22
34 79   6  8 498         0.    2.75  4.0 -100.   53.   368.   378.   973.  2440.  3643.  3486.      0. G-05-23
35 79   6 11 522         0.    2.50  5.6 -100.   46.   460.   460.  1068.  2888.  4103.  4067.      0. G-04-19
36 79   6 13 554         0.    2.75  4.3 -100.   50.   407.   424.   946.  2828.  3360.  3501.      0. G-01-20
37 79   6 14 570         0.    2.00  5.3 -100.   38.   538.   582.  1265.  2776.  4589.  4863.      0. G-08-21
38 79   6 15 600         0.    2.75  6.6 -100.   52.   403.   400.   902.  2281.  4060.  4060.      0. G-02-19
39 79   6 18 618         0.    2.00  6.4 -100.   55.   651.   685.  1557.  3431.  5323.  5128.      0. G-03-21
```

Figure 2. Contents of initial file 'F1'

Restart File

11. The program limits the number of samples that can be processed in the initial run to 60. However, the restart option of the program permits the user to process a total of 480 samples. When the user requests that a restart file be generated, the program writes the cumulative sums and other information needed to continue the analysis to a restart file in accordance with lines 1 through 6 and 6A through 6H of Figure 1. An example showing the contents of a restart file as written by the program is presented in Figure 3. New sample data (maximum of 59 samples) are added to the end of the restart file in accordance with lines 7 through 9 of Figure 1. An example of the updated restart file is presented in Figure 4.

12. During the execution of the program, the statistical output is displayed for only the values contained in the present restart file. However, data for predicted strengths are displayed for all samples. Graphs of the restart data can be scaled by the user to overlap with graphs from previous runs. As many restart files as needed can be processed so long as no more than 480 total samples are entered. It is important to note that the values for the required average strength are computed exclusively from the strength results contained in the restart file being processed and not from previous test results.

Undefined Values

13. Certain input values that are not defined and are to be omitted in the statistical analysis can be processed by the program when entered as follows:

Input Description	Entry for Undefined Value
Air content	0
Sample slump	0
Sample water:cement ratio	0
Test specimen strength	0
Temperature of air	-100
Temperature of concrete	-100

```
1       7
2       1       1       7      28      90      90     365
3 RICHARD B RUSSELL
4 DACW78-21-C0084
5 TOT12
6      90      2000.       1.282       6.00       0.67
6       2      0.950      30      65.50      30      162.8
6      29       349.
6      10.       3.     11.     10.     10.      0.     17.     24.      3.     14.
6      29      5695.
6     212.     283.    707.    212.    177.     36.    141.    283.      0.    195.
6      30     13317.         6265911.     460.     416.     550.     402.     658.
6      30     31128.        34314802.    1008.     946.    1265.     902.    1557.
6      30     76884.       205699332.    2688.    2228.    2776.    2281.    3431.
6      30    120605.       500248460.    4085.    3431.    4722.    4050.    5226.
6       0         0.              0.       0.       0.       0.       0.       0.
6       0.30       0.65       265.       665.
6       495.      1619.       999.      3537.      1786.      5535.
6          0.          0.
6      30                0.                  0.
6                        0.                  0.                          0.
6     267.    1786.    265.    3316.    327.    3908.    305.    3891.    336.    3714.
6     380.    3767.    358.    3926.    351.    3183.    622.    4943.    635.    4015.
6     375.    4342.    591.    5447.    430.    4041.    531.    4501.    488.    4351.
6     470.    4200.    588.    4704.    536.    3873.    511.    3776.    420.    3856.
6     422.    3873.    533.    5111.    377.    4156.    345.    2865.    373.    3555.
6     460.    4085.    416.    3431.    550.    4722.    402.    4050.    658.    5226.
```

Figure 3. Contents of restart file 'F2' as written by the program

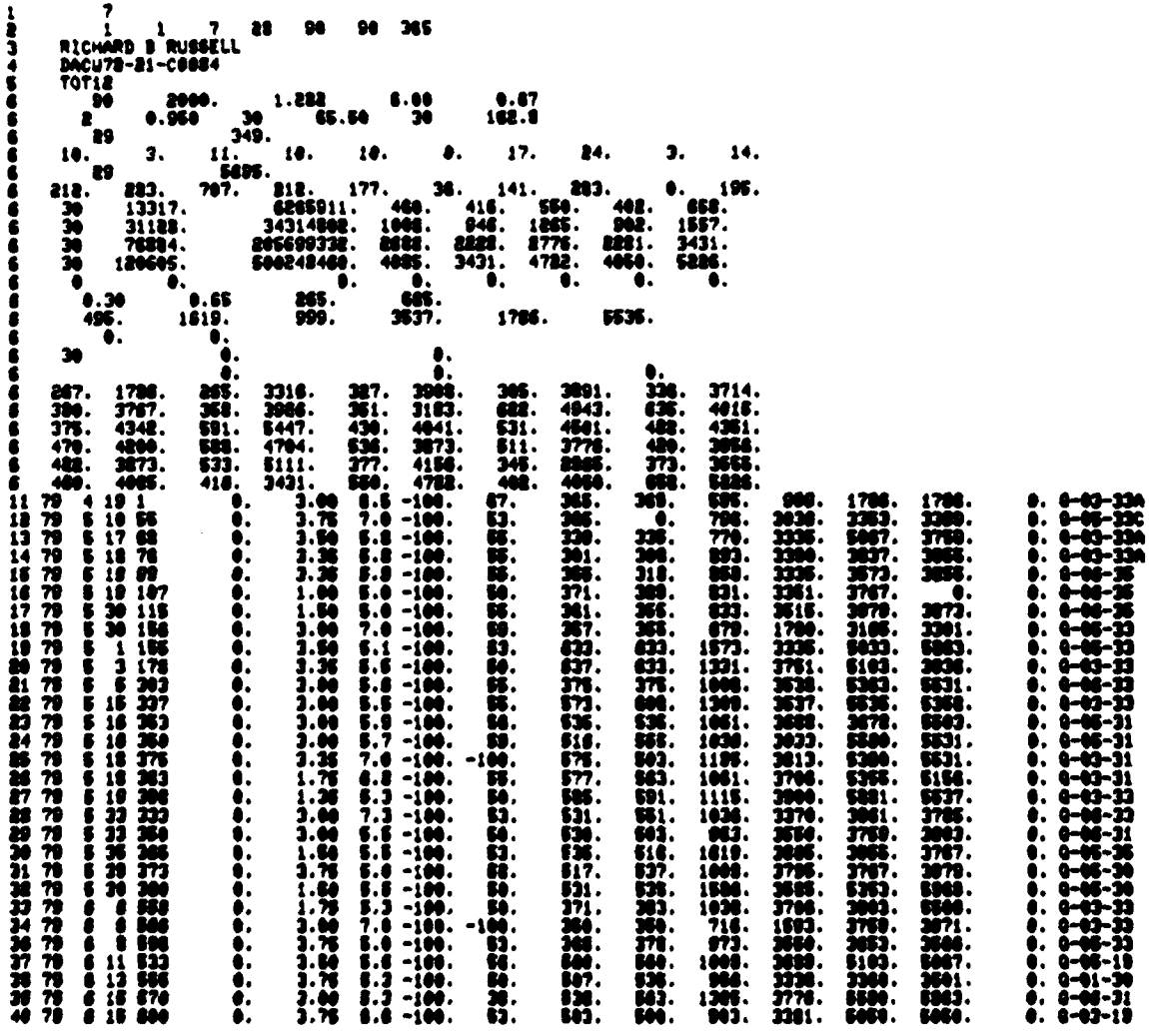

Figure 4. Contents of restart file 'F2' after new data added

All other values associated with the undefined input are designated as undefined by the program. The undefined values appear as '****' in the tabular displays. These values are omitted from the graph displays.

14. Some age groups contain two test specimens. When one of these test values is undefined, the number of tests for the overall-sample data is increased by one; however, the number of tests for the within-sample data is not. For each such occurrence, this results in the difference for the number of tests between overall-sample and within-sample data being increased by one. This is reflected in the plots for (a) "Standard Deviation and Range Versus Number of Tests" and (b) "Coefficient of Variation Versus Number of Tests."

Data Entry

15. Data can be entered into the program in one of three ways: (1) from an existing file, (2) from the terminal, and (3) part from an existing file and part from the terminal. Data from the terminal are entered through a series of interactive question/answer responses as illustrated in Figure 5. Additional lines of data can be added to data from an existing data file through the same series of question/answer responses as illustrated in Figure 6. Data entered through this interactive option of the program are automatically written to an output file. An Edit system such as the one on the Honeywell computer at WES can be used to correct the contents of a data file as illustrated in Figure 7.

```
ENTER DEVICE SPEED(30 OR 120) - 120
DO YOU WISH TO ENTER DATA FROM TERMINAL(Y OR N) - Y
ENTER NAME OF OUTPUT FILE - EXAMPLE1
IS PART OF DATA TO BE ENTERED FROM A FILE(Y OR N) - N
IS INPUT DATA FROM A RESTART FILE(Y OR N) - N
DO YOU WISH TO ANALYZE FIELD DATA(Y OR N) - Y
IS STRUCTURAL CONCRETE TO BE ANALYZED(Y OR N) - N

TO TERMINATE INTERACTIVE BUILD MODE ENTER 'DONE'
------------------------------------------------

ENTER NUMBER OF TESTS PER SAMPLE(MAX VALUE OF 7)
- 7

ENTER TEST AGES
- 1 1 7 28 90 90 365

ENTER PROJECT
- RICHARD B RUSSELL

ENTER CONTRACT NUMBER
- DACW78-21-C0084

ENTER MIX NUMBER
- TOT12

ENTER  1)DESIGN AGE,  2)DESIGN STRENGTH,'  3)T-DISTRIBUTION FACTOR,
       4)MAXIMUM SIZE AGGREGATE,  5)DESIGN WATER-CEMENT RATIO

- 90 2000 1.282 6 .67

FOR SAMPLE  1
-------------
ENTER  1)YEAR(I2),  2)MONTH(I2),  3)DAY(I2),'  4)SAMPLE ID NO.(A8),
       5)WATER-CEMENT RATIO,'  6)SLUMP,  7)AIR CONTENT,
       8)AIR TEMPERATURE,  9)CONCRETE TEMPERATURE
- DONE

DO YOU WISH TO MAKE ANOTHER RUN(Y OR N) - N

#LIST EXAMPLE1

1       7
2       1    1    7   28   90   90  365
3    RICHARD B RUSSELL
4    DACW78-21-C0084
5    TOT12
6       90     2000.     1.282      6.00      0.67
```

Figure 5. Example of program being used to build a new data file

```
ENTER DEVICE SPEED(30 OR 120) - 120
DO YOU WISH TO ENTER DATA FROM TERMINAL(Y OR N) - Y
ENTER NAME OF OUTPUT FILE - EXAMPLE2
IS PART OF DATA TO BE ENTERED FROM A FILE(Y OR N) - Y
ENTER NAME OF INPUT FILE - EXAMPLE1
IS INPUT DATA FROM A RESTART FILE(Y OR N) - N
DO YOU WISH TO ANALYZE FIELD DATA(Y OR N) - Y
IS STRUCTURAL CONCRETE TO BE ANALYZED(Y OR N) - N

TO TERMINATE INTERACTIVE BUILD MODE ENTER 'DONE'
------------------------------------------------

FOR SAMPLE  1
-------------
ENTER  1)YEAR(I2),  2)MONTH(I2),  3)DAY(I2),'  4)SAMPLE ID NO.(A8),
       5)WATER-CEMENT RATIO,'  6)SLUMP,  7)AIR CONTENT,
       8)AIR TEMPERATURE,  9)CONCRETE TEMPERATURE
- 79 3 19 1 .3 2 6.5 -100 67

ENTER STRENGTH VALUES ORDERED BY TEST AGE
- 265 289 495 9999 1786 1786 0

ENTER SAMPLE REMARKS(NO BLANKS ALLOWED)
- G-82-23A

FOR SAMPLE  2
-------------
ENTER  1)YEAR(I2),  2)MONTH(I2),  3)DAY(I2),'  4)SAMPLE ID NO.(A8),
       5)WATER-CEMENT RATIO,'  6)SLUMP,  7)AIR CONTENT,
       8)AIR TEMPERATURE,  9)CONCRETE TEMPERATURE
- DONE

DO YOU WISH TO MAKE ANOTHER RUN(Y OR N) - N

#LIST EXAMPLE2

1       7
2       1    1    7   28   90   90  365
3       RICHARD B RUSSELL
4       DACW78-21-C0084
5       TOT12
6       90      2000.      1.282      6.00      0.67
11 79  3 19 1         0.30  2.00  6.5 -100.   67.    265.   289.   495.  9999.  1786.  1786.     0. G-82-23A
```

Figure 6. Example of program being used to add new data to an existing file

```
*LIST EXAMPLE2

1        7
2        1    1    7   28   90   90  365
3       RICHARD B RUSSELL
4       DACW78-21-C0084
5       TOT12
6       90      2000.      1.282      6.00      0.67
11 79  3 19 1         0.30  2.00  6.5 -100.   67.   265.   269.   495.  9999.  1786.  1786.     0. G-02-23A

*EDIT 0 EXAMPLE2
-F:/11/ RUS:/99/:/ 9/

11 79  3 19 1         0.30  2.00  6.5 -100.   67.   265.   269.   495.   999.  1786.  1786.     0. G-02-23A

-DONE
*RESA EXAMPLE2
DATA SAVED-EXAMPLE2
```

Figure 7. Example of Edit system being used to correct contents of an existing file

PART V: EQUATIONS

16. Equations used by the program to compute the displayed output data are as follows:

For Linear Regression of Accelerated Versus Design-Age Strengths

Description of Output	Equation Used by Program
Slope	$b = \dfrac{\Sigma X_i Y_i - \dfrac{\Sigma X_i \Sigma Y_i}{n}}{\Sigma X_i^2 - \dfrac{(\Sigma X_i)^2}{n}}$
Y-intercept	$a = \dfrac{\Sigma Y_i - b\Sigma X_i}{n}$
Correlation coefficient	$cc = b\sqrt{\dfrac{\Sigma X_i^2 - \dfrac{(\Sigma X_i)^2}{n}}{\Sigma Y_i^2 - \dfrac{(\Sigma Y_i)^2}{n}}}$
95% confidence interval	$ci = t\sqrt{\dfrac{1}{n-2}\left[\Sigma Y_i^2 - \dfrac{(\Sigma Y_i)^2}{n} - b^2\left(\Sigma X_i^2 - \dfrac{(\Sigma X_i)^2}{n}\right)\right]}$

where a = Y-intercept

b = Slope

cc = Correlation coefficient

ci = 95% confidence interval (see Appendix B for derivation)

n = Number of points

t = t-distribution factor for 95% confidence interval; for n = 1 to 29 , t-distribution factor is 12.706, 4.303, 3.182, 2.776, 2.571, 2.447, 2.365, 2.306, 2.262, 2.228, 2.201, 2.179, 2.160, 2.145, 2.131, 2.120, 2.110, 2.101, 2.093, 2.086, 2.080, 2.074, 2.069, 2.064, 2.060, 2.056, 2.052, 2.048, and 2.045, respectively; for $n \geq 30$, t-distribution factor is 1.960.

X_i = An individual accelerated strength

Y_i = An individual design-age strength

For Predicted Design-Age Strengths

Description of Output	Equation Used by Programs
Predicted design-age strength	$Y_p = a + b\,X_i$
Average strength	$\bar{X} = \frac{X_1 + X_2 + X_3 \ldots\ldots + X_n}{n}$
Standard error of estimate	$S = \sqrt{\frac{\Sigma d^2}{n}}$

where a = Y-intercept from laboratory regression curve

b = Slope from laboratory regression curve

d = Difference between accelerated and predicted strengths

n = Number of pairs of actual and predicted design-age strengths

S = Standard error of estimate

X_i = An individual accelerated strength

$\bar{X}$ = Average strength

Y_p = Predicted design-age strength

For Required Strengths

Description of Output	Equation Used by Program
Required average strength for design-age test specimens	$f_{cr} = f'_c + t*\sigma_d$
Required accelerated strength	$f_{ca} = \frac{f'_c - a}{b}$
Required average accelerated strength when $n \geq 30$	$f_{cra} = f_{ca} + t*\sigma_a$
Required average accelerated strength when $10 \leq n < 30$	$f_{cra} = f_{ca} + t*\sigma_a + t'*S_{y \cdot x}$

where a = Y-intercept from laboratory regression curve

b = Slope from laboratory regression curve

f'_c = Specified strength

f_{ca} = Required accelerated strength

f_{cr} = Required average strength

f_{cra} = Required average accelerated strength

n = Number of pairs of accelerated and design-age strengths on laboratory regression curve

σ_a = Standard deviation of accelerated-age strengths contained in current file only

σ_d = Standard deviation of design-age strengths contained in current file only

$S_{y \cdot x}$ = The standard error of estimate of Y values for a given X value using $n - 2$ degrees of freedom (See Appendix B for derivation)

t = A constant multiplier for standard deviation (σ) that depends on the number of tests expected to fall below f'_c (ACI 214-77, Table 4.1)

t' = A constant multiplier for standard error of estimate when $10 \leq n \leq 30$ (ACI 214-77, Table 4.2)

For Statistical Analysis of Strength Test Results

Description of Output	Equation Used by Program
Average of test results	$\bar{X} = \frac{X_1 + X_2 + X_3 \ldots\ldots + X_n}{n}$
Average of last-m tests	$X_{Lm} = \frac{X_{n-m+1} + X_{n-m+2} \ldots\ldots X_n}{m}$
Standard deviation	$\sigma = \sqrt{\frac{\Sigma X_i^2 - \frac{(\Sigma X_i)^2}{n}}{n-1}}$
Coefficient of variation	$V = 100 \frac{\sigma}{\bar{X}}$
Within-sample, 2-test specimen average	$X_{iAB} = \frac{X_{iA} + X_{iB}}{2}$
Actual range	$R_i = \lvert X_{iA} - X_{iB} \rvert$

Average range

$$\bar{R} = \frac{R_1 + R_2 + R_3 \ldots\ldots + R_n}{n}$$

Average of last-10 ranges

$$R_{L10} = \frac{R_{n-9} + R_{n-8} \ldots\ldots + R_n}{10}$$

Within-sample coefficient of variation

$$VW = \frac{100\left(\frac{1}{d_2}\right)\bar{R}}{\bar{X}}$$

Actual within-sample coefficient of variation

$$VW_{act} = \frac{100\left(\frac{1}{d_2}\right)R_i}{\bar{X}}$$

where $\frac{1}{d_2}$ = 0.8865; 2-test specimen value for computing within-sample standard deviation (ACI 214-77, Table 3.4.1)

f'_c = Specified strength

m = 3 for analysis of structural concrete
= 5 for analysis of nonstructural concrete

n = Number of tests

R_i = Actual range

R_{L10} = Average of last 10 ranges

s = Standard deviation

V = Coefficient of variation

VW = Within-sample coefficient of variation

VW_{act} = Actual within-sample coefficient of variation

X_i = An individual test result

X_{iA} = One of two within-sample strengths

X_{iB} = Second of two within-sample strengths

X_{iAB} = Within-sample, 2-test specimen average

X_{Lm} = Average of last-m tests

$\bar{X}$ = Average strength

PART VI: EXECUTION

17. The program is executed through a series of interactive question and answer reponses between the computer and the user, respectively. For processing laboratory strength test results, Figure 8 can be used as a guide for a step-by-step execution of the program. In this example, the data are being read from an initial file (Figure 2).

18. The slope, Y-intercept, number of points on curve, and 95 percent confidence interval for the regression curve produced from the analysis of laboratory data are required as input in processing field strength test results. If regression data are based on 30 or more data points, the 95 percent confidence interval is not required as input. Figure 9 and Figure 10 can be used as guides for a step-by-step execution of the program in processing field data. In Figure 9, the analysis is being made using an initial data file (Figure 2). In Figure 10, the analysis is being continued using a restart file (Figure 4). In Figures 8-10, nonstructural concrete is being analyzed.

For WES or MACON systems:

```
*RUN WESLIB/CORPS/X0064,R
```

For BOEING system:

```
C>OLD,CORPS/UN=CECELB
C>CALL,CORPS,X0064
```

```
ENTER DEVICE SPEED(30 OR 120) - 120
DO YOU WISH TO ENTER DATA FROM TERMINAL(Y OR N) - N
ENTER NAME OF INPUT FILE - L1
IS INPUT DATA FROM A RESTART FILE(Y OR N) - N
DO YOU WISH TO ANALYZE FIELD DATA(Y OR N) - N
ENTER UNITS FOR SLUMP(A2),STRENGTH(A3) AND TEMPERATURE(A1) - IN PSI F
ENTER NUMBER OF COPIES OF OUTPUT TO BE MADE - 3
DO YOU WISH TO LIST TABLES(Y OR N) - Y
DO YOU WISH TO LIST SUMMARY TABLE(Y OR N) - Y
```


Figure 8. Example showing a step-by-step execution of program using an initial file that contains laboratory test results (Sheet 1 of 8)

U.S. ARMY CORPS OF ENGINEERS
EVALUATION OF CONCRETE STRENGTH DATA

PAGE: 1
DATE:02/24/83
TIME: 16:29

PROJECT: RICHARD B RUSSELL
CONTRACT: DACW28-21-C0084
F'C: 2000. T: 1.282

MIX: TC712
DESIGN AGE: 90-DAY
MAX SIZE AGGR: 6.00

SUMMARY TABLE

RANGE OF WATER/CEMENT RATIO	=	0.30	TO	0.65
RANGE OF 90-DAY COMPRESSIVE STRENGTHS,PSI	=	1786.	TO	5535.

LINEAR REGRESSION OF 1-DAY AND DESIGN AGE(90-DAY) LAB DATA

EQUATION FOR LAB DATA IS	:	Y(90-DAY) = 1822. + 4.953*X(1-DAY)
NO. OF POINTS ON CURVE IS	:	30
95% CONFIDENCE INTERVAL IS	:	958.36
CORRELATION COEFFICIENT IS	:	0.7519

Figure 8. (Sheet 2 of 8)

```
DO YOU WISH TO LIST INPUT DATA(Y OR N) - Y
```

Figure 8. (Sheet 3 of 8)

U.S. ARMY CORPS OF ENGINEERS
EVALUATION OF CONCRETE STRENGTH DATA

PAGE: 2
DATE: 02/24/83
TIME: 16:29

PROJECT: RICHARD B RUSSELL
CONTRACT: DACW28-81-C0084
F'C: 2000. T: 1.282

MIX: TOT12
DESIGN AGE: 90-DAY
MAX SIZE AGGR: 6.00

BATCH INPUT

MIX DATE							TEMP F		
YR	MO	DA	SAMPLE NUMBER	W/C	SLUMP (IN)	AIR (%)	AIR	CONC	REMARKS
79	3	19	1	0.30	2.00	6.5	****	67.	G-02-23A
79	4	10	55	0.65	2.75	7.0	****	53.	G-04-23C
79	4	17	68	****	2.50	4.8	****	54.	G-02-23A
79	4	18	76	****	2.25	5.8	****	45.	G-02-23A
79	4	19	99	****	2.25	4.8	****	54.	G-06-24
79	4	19	107	****	1.00	4.0	****	50.	G-06-24
79	4	20	115	****	1.50	4.0	****	55.	G-06-24
79	4	30	146	****	2.00	7.0	****	49.	g-04-22
79	5	1	154	****	2.50	6.1	****	53.	g-04-22
79	5	2	178	****	2.25	5.4	****	50.	g-02-22
79	5	4	202	****	2.00	4.6	****	54.	g-06-22
79	5	14	227	****	2.00	4.4	****	55.	g-03-23
79	5	16	242	****	3.00	4.9	****	46.	g-04-21
79	5	16	250	****	2.00	5.7	****	48.	g-04-21
79	5	18	274	****	2.25	7.0	****	****	g-02-21
79	5	18	282	****	1.75	6.8	****	55.	G-02-21
79	5	19	298	****	1.25	4.2	****	50.	G-03-23
79	5	23	332	****	3.00	7.2	****	53.	G-06-22
79	5	23	340	****	2.00	4.4	****	60.	G-06-21
79	6	25	364	****	1.50	5.4	****	48.	G-05-24
79	5	29	372	****	2.75	5.0	****	48.	G-04-20
79	5	30	380	****	1.50	5.4	****	50.	G-04-20
79	6	6	458	****	1.75	5.2	****	50.	G-03-22
79	6	6	466	****	3.00	7.0	****	****	G-03-22
79	6	8	498	****	2.75	4.0	****	53.	G-05-23
79	6	11	522	****	2.50	5.6	****	46.	G-04-19
79	6	13	554	****	2.75	4.3	****	50.	G-01-20
79	6	14	570	****	2.00	5.3	****	38.	G-06-21
79	6	15	600	****	2.75	8.6	****	52.	G-02-19
79	6	18	616	****	2.00	5.4	****	56.	G-03-21

Figure 8. (Sheet 4 of 8)

U.S. ARMY CORPS OF ENGINEERS
EVALUATION OF CONCRETE STRENGTH DATA

PAGE: 3
DATE: 02/24/83
TIME: 16:29

PROJECT: RICHARD B RUSSELL
CONTRACT: DACW78-21-C0084
F'C: 2000. T: 1.282

MIX: TOT12
DESIGN AGE: 90-DAY
MAX SIZE AGGR: 6.00

TEST RESULTS

MIX DATE				CYLINDER STRENGTH (PSI)						
YR	MO	DA	SAMPLE NUMBER	1-D	1-D	7-D	28-D	90-D	90-D	365-D
79	3	19	1	265	269	495	999	1786	1786	#####
79	4	10	55	265	#####	796	2036	3342	3289	#####
79	4	17	68	329	325	770	2335	4067	3749	#####
79	4	18	76	301	308	893	2290	3837	3944	#####
79	4	19	99	354	318	858	2326	3572	3856	#####
79	4	19	107	371	389	831	2341	3767	#####	#####
79	4	20	115	361	364	833	2414	3979	3873	#####
79	4	30	146	347	364	879	1760	3185	3201	#####
79	5	1	164	622	622	1478	3334	5022	4883	#####
79	5	2	178	637	633	1281	2741	4103	3986	#####
79	5	4	202	375	376	1008	2538	4262	4421	#####
79	5	14	227	573	608	1309	3537	5535	5368	#####
79	5	16	242	424	435	1061	2688	3678	4403	#####
79	5	16	250	516	546	1026	3033	4580	4421	#####
79	5	18	274	474	508	1185	2812	4288	4421	#####
79	5	18	282	477	463	1061	2706	4244	4156	#####
79	5	19	298	584	591	1114	2900	4881	4627	#####
79	5	23	332	531	541	1026	2370	3961	3784	#####
79	5	23	340	520	502	982	2440	3749	3802	#####
79	5	25	364	424	416	1619	2885	3944	3767	#####
79	5	29	372	417	427	1008	2794	3767	3979	#####
79	5	30	380	531	534	1486	3484	5252	4969	#####
79	6	6	458	371	382	1028	2706	3802	4609	#####
79	6	6	466	340	350	716	1592	2759	2971	#####
79	6	8	498	368	378	973	2440	3643	3466	#####
79	6	11	522	460	460	1008	2688	4103	4067	#####
79	6	13	554	407	424	946	2228	3360	3501	#####
79	6	14	570	538	562	1265	2776	4580	4883	#####
79	6	15	600	403	400	902	2281	4050	4050	#####
79	6	18	616	651	665	1657	3431	5323	5128	#####

Figure 8. (Sheet 5 of 8)

```
DO YOU WISH TO PLOT DATA(Y OR N) - Y

DO YOU WANT REPLOT CABILITIES(Y OR N) - N

DO YOU WISH TO PLOT REGRESSION CURVES(Y OR N) - Y

REGRESSION PLOT
ENTER BEGINNING AND ENDING TEST NUMBERS TO BE PLOTTED - 1 30
```

Figure 8. (Sheet 6 of 8)

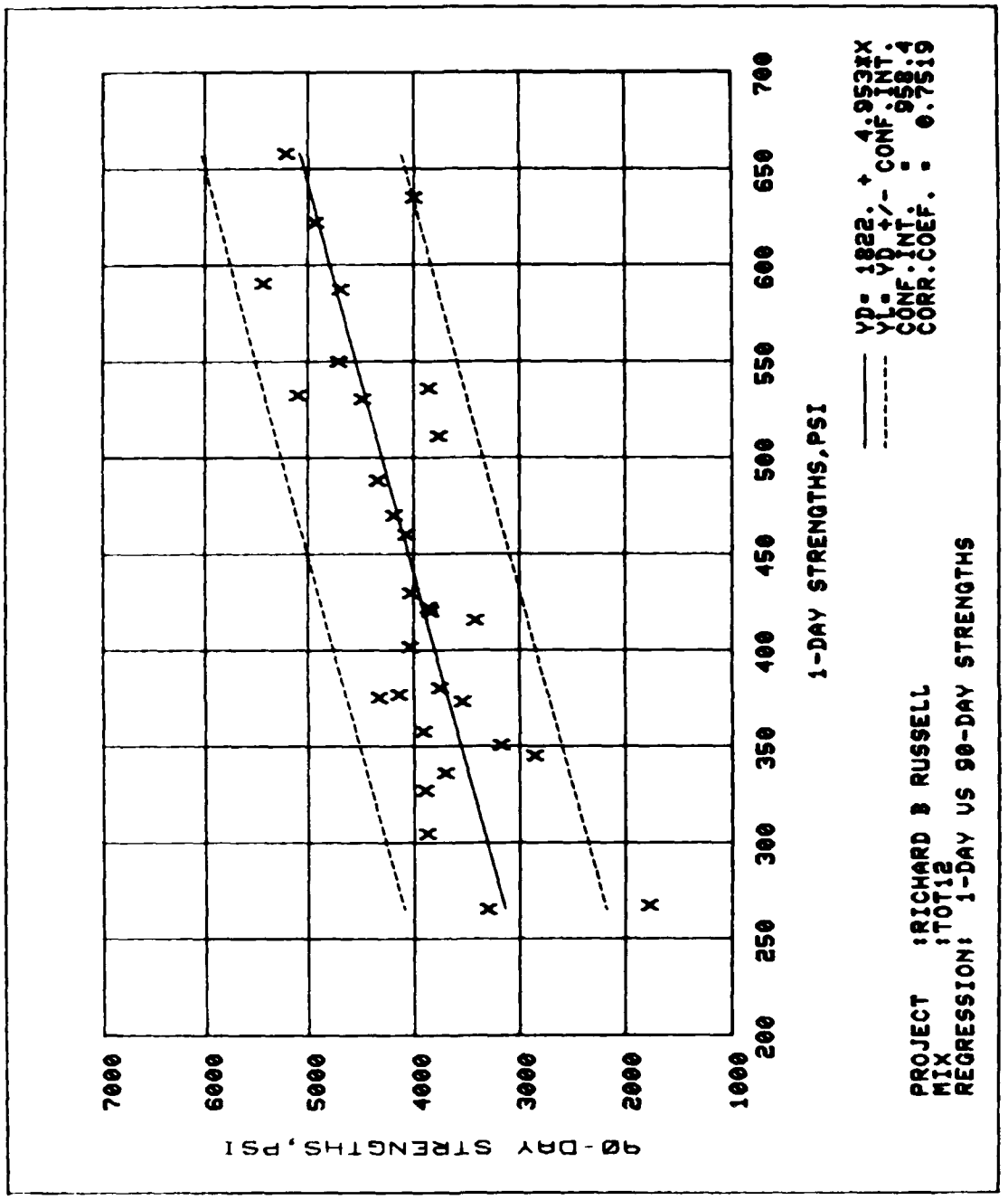

Figure 8. (Sheet 7 of 8)

```
DO YOU WISH TO REPLOT REGRESSION CURVE(Y OR N) - N
DO YOU WISH TO RETURN TO TABLE OPTION(Y OR N) - N
DO YOU WISH TO RETURN TO PLOT OPTION(Y OR N) - N
IS RESTART FILE TO BE GENERATED(Y OR N) - N
DO YOU WISH TO MAKE ANOTHER RUN(Y OR N) - N
*
```

Figure 8. (Sheet 8 of 8)

For WES or MACON systems:

```
*RUN WESLIB/CORPS/X0064,R
```

For BOEING system:

```
C>OLD,CORPS/UN=CECELB
C>CALL,CORPS,X0064
```

```
ENTER DEVICE SPEED(30 OR 120) - 120

DO YOU WISH TO ENTER DATA FROM TERMINAL(Y OR N) - N

ENTER NAME OF INPUT FILE - F1

IS INPUT DATA FROM A RESTART FILE(Y OR N) - N

DO YOU WISH TO ANALYZE FIELD DATA(Y OR N) - Y

IS STRUCTURAL CONCRETE TO BE ANALYZED(Y OR N) - N

ENTER SLOPE,Y-INTERCEPT, AND NO. POINTS
FOR LABORATORY REGRESSION CURVE - 4.953 1822 30

ENTER UNITS FOR SLUMP(A2),STRENGTH(A3) AND TEMPERATURE(A1) - IN PSI F

ENTER NUMBER OF COPIES OF OUTPUT TO BE MADE - 3

DO YOU WISH TO LIST TABLES(Y OR N) - Y

DO YOU WISH TO LIST SUMMARY TABLE(Y OR N) - Y
```

Figure 9. Example showing a step-by-step execution of program using an initial file that contains field test results (Sheet 1 of 27)

U.S. ARMY CORPS OF ENGINEERS
EVALUATION OF CONCRETE STRENGTH DATA

PAGE: 1
DATE: 02/24/83
TIME: 17:10

PROJECT: RICHARD B RUSSELL
CONTRACT: DACW78-81-C0084
F'C: 2000. T: 1.282 MAX SIZE AGGR: 6.00

MIX: TCT12
DESIGN AGE: 90-DAY
W/C: 0.67

SUMMARY TABLE

AVERAGE WATER/CEMENT RATIO	•	0.48
AVERAGE SLUMP, IN	•	2.18
AVERAGE AIR CONTENT,%	•	5.4
REQUIRED 1-DAY ACCELERATED STRENGTH,PSI	•	36.
REQUIRED AVERAGE 1-DAY ACCELERATED STRENGTH,PSI	•	178.
SPECIFIED STRENGTH FOR 90-DAY STRENGTHS,PSI	•	2000.
REQUIRED AVERAGE 90-DAY STRENGTH,PSI	•	2934.

AGE	NO. TEST	SUM OF TEST	SUM OF TESTS SQUARED	TEST AVERAGE	AVE. RANGE	COEF. VARIATION WITHIN SAMPLE	COEF. VARIATION WITHIN GROUP	STD DEV
		PSI	PSI**2	PSI	PSI	%	%	PSI
1	30	13317.	6265911.	444.	12.	2.4	24.9	111.
7	30	31128.	34314802.	1038.	*****	*******	25.4	264.
28	30	76884.	205699332.	2563.	*****	*******	21.3	546.
90	30	120605.	500248468.	4020.	196.	4.3	18.1	729.
365	0	0.	0.	0.	*****	*******	0.	0.

LINEAR REGRESSION OF 1-DAY AND DESIGN AGE(90-DAY) LAB DATA

EQUATION FOR LAB DATA IS : Y(90-DAY) = 1822. + 4.953**X(1-DAY)
NO. OF POINTS ON CURVE IS : 30

Figure 9. (Sheet 2 of 27)

DO YOU WISH TO LIST PREDICTED STRENGTHS(Y OR N) - Y

Figure 9. (Sheet 3 of 27)

PROJECT: RICHARD B RUSSELL
CONTRACT: DACW78-21-C0084
F'C: 2000. T: 1.282 SIZE AGGR: 6.00

MIX: TOT12
DESIGN AGE: 90-DAY
W/C: 0.67

PREDICTED STRENGTHS

N	STRENGTH				
	ACCELERATED 1-DAY (PSI)	PREDICTED 90-DAY (PSI)	ACTUAL 90-DAY (PSI)	DIFFERENCE 90-DAY (PSI)	DIFFERENCE 90-DAY (%)
1	267.	3144.	1786.	-1358.5	-76.1
2	265.	3135.	3316.	181.0	5.5
3	327.	3442.	3908.	466.4	11.9
4	305.	3330.	3891.	560.3	14.4
5	336.	3486.	3714.	227.3	6.1
6	380.	3704.	3767.	62.9	1.7
7	358.	3593.	3926.	333.3	8.5
8	351.	3558.	3183.	-375.0	-11.8
9	622.	4903.	4943.	39.7	0.8
10	635.	4967.	4015.	-952.7	-23.7
11	376.	3679.	4342.	662.1	15.3
12	591.	4747.	5447.	699.8	12.8
13	430.	3949.	4041.	91.8	2.3
14	531.	4458.	4501.	50.9	1.1
15	488.	4239.	4351.	111.4	2.6
16	470.	4150.	4200.	50.1	1.2
17	588.	4732.	4704.	-27.9	-0.6
18	536.	4477.	3873.	-604.3	-15.6
19	511.	4353.	3776.	-577.5	-15.3
20	420.	3902.	3856.	-46.8	-1.2
21	422.	3912.	3873.	-39.2	-1.0
22	533.	4459.	5111.	651.0	12.7
23	377.	3687.	4156.	468.7	11.3
24	345.	3531.	2865.	-665.8	-23.2
25	373.	3669.	3555.	-115.0	-3.2
26	460.	4100.	4085.	-15.4	-0.4
27	416.	3880.	3431.	-449.5	-13.1
28	550.	4546.	4722.	175.3	3.7
29	402.	3811.	4050.	239.4	5.9
30	658.	5081.	5226.	144.4	2.8
AVERAGE	444.	4021.	4020.	xxxxxxxx	xxxxxxxxx
STD ERROR OF EST.	xxxxxxxxxx	xxxxxxxxxx	xxxxxxxxx	472.4	17.3

Figure 9. (Sheet 4 of 27)

```
DO YOU WISH TO LIST INPUT DATA(Y OR N) - Y
```


Figure 9. (Sheet 5 of 27)

U.S. ARMY CORPS OF ENGINEERS
EVALUATION OF CONCRETE STRENGTH DATA

DATE:02/24/83
TIME: 16:38

PROJECT: RICHARD B RUSSELL
CONTRACT: DACW78-21-C0084
F'CI 2000. TI 1.282 MAX SIZE AGGR: 6.00

MIX: TOT:2
DESIGN AGE: 90-DAY
W/C: 0.67

BATCH INPUT

MIX DATE			SAMPLE		SLUMP	AIR	TEMP F		
YR	MO	DA	NUMBER	W/C	(IN)	(%)	AIR	CONC	REMARKS
79	3	19	1	0.30	2.00	6.5	****	67.	G-02-23A
79	4	10	55	0.65	2.75	7.0	****	53.	G-04-23C
79	4	17	68	****	2.50	4.8	****	54.	G-02-23A
79	4	18	76	****	2.25	5.8	****	45.	G-02-23A
79	4	19	99	****	2.25	4.8	****	54.	G-06-24
79	4	19	107	****	1.00	4.0	****	50.	G-06-24
79	4	20	115	****	1.50	4.0	****	55.	G-06-24
79	4	30	146	****	2.00	7.0	****	48.	g-04-22
79	5	1	154	****	2.50	5.1	****	53.	g-04-22
79	5	2	178	****	2.25	5.4	****	60.	g-02-22
79	5	4	202	****	2.00	4.6	****	64.	g-06-22
79	5	14	227	****	2.00	4.4	****	55.	g-03-23
79	5	16	242	****	3.00	4.9	****	48.	g-04-21
79	5	16	250	****	2.00	5.7	****	49.	g-04-21
79	5	18	274	****	2.25	7.0	****	****	g-02-21
79	5	18	282	****	1.75	6.8	****	56.	G-02-21
79	5	19	298	****	1.25	4.2	****	50.	G-03-23
79	6	23	332	****	3.00	7.2	****	53.	G-06-22
79	6	23	340	****	2.00	4.4	****	60.	G-06-21
79	5	25	364	****	1.50	5.4	****	42.	G-05-24
79	5	29	372	****	2.75	6.0	****	48.	G-04-20
79	5	30	380	****	1.50	5.4	****	50.	G-04-20
79	6	6	458	****	1.75	5.2	****	50.	G-03-22
79	6	6	466	****	3.00	7.0	****	****	G-03-22
79	6	8	498	****	2.75	4.0	****	53.	G-05-23
79	6	11	522	****	2.50	5.6	****	46.	G-04-19
79	6	13	554	****	2.75	4.3	****	50.	G-01-20
79	6	14	570	****	2.00	5.3	****	38.	G-06-21
79	6	15	600	****	2.75	6.6	****	52.	G-02-19
79	6	18	616	****	2.00	5.4	****	55.	3-03-21

Figure 9. (Sheet 6 of 27)

U.S. ARMY CORPS OF ENGINEERS
EVALUATION OF CONCRETE STRENGTH DATA

DATE:02/24/83
TIME: 16:38

PROJECT: RICHARD B RUSSELL
CONTRACT: DACW78-21-C0084
F'C: 2000. T: 1.282 MAX SIZE AGGR: 6.00

MIX: T0T12
DESIGN AGE: 90-DAY
W/C: 0.67

TEST RESULTS

MIX DATE				CYLINDER STRENGTH (PSI)						
YR	MO	DA	SAMPLE NUMBER	1-D	1-D	7-D	28-D	90-D	90-D	365-D
79	3	19	1	265	269	495	999	1786	1786	*****
79	4	10	55	265	*****	796	2036	3342	3289	*****
79	4	17	68	329	325	770	2335	4067	3749	*****
79	4	18	76	301	308	893	2290	3837	3944	*****
79	4	19	99	354	318	858	2325	3572	3856	*****
79	4	19	107	371	389	831	2341	3767	*****	*****
79	4	20	115	361	354	833	2414	3979	3873	*****
79	4	30	146	347	354	679	1760	3165	3201	*****
79	5	1	154	622	622	1472	3334	5022	4863	*****
79	5	2	178	637	633	1221	2741	4103	3926	*****
79	5	4	202	375	375	1008	2538	4262	4421	*****
79	5	14	227	573	608	1309	3637	5535	5358	*****
79	5	16	242	424	436	1061	2688	3678	4403	*****
79	5	16	250	516	545	1026	3033	4680	4421	*****
79	5	18	274	474	502	1185	2812	4280	4421	*****
79	5	18	282	477	463	1061	2706	4244	4156	*****
79	5	19	298	584	591	1114	2900	4881	4527	*****
79	5	23	332	531	541	1026	2370	3961	3784	*****
79	5	23	340	520	502	982	2440	3749	3802	*****
79	5	25	364	424	416	1619	2886	3944	3767	*****
79	5	29	372	417	427	1008	2794	3767	3979	*****
79	5	30	380	631	534	1486	3484	5252	4969	*****
79	6	6	458	371	382	1028	2706	3802	4509	*****
79	6	6	466	340	350	716	1592	2759	2971	*****
79	6	8	498	368	378	973	2440	3643	3466	*****
79	6	11	522	460	460	1008	2688	4103	4067	*****
79	6	13	554	407	424	946	2228	3360	3501	*****
79	6	14	570	538	562	1265	2776	4580	4863	*****
79	6	15	600	403	400	902	2281	4050	4050	*****
79	6	18	616	651	665	1557	3431	5323	5128	*****

Figure 9. (Sheet 7 of 27)

```
ENTER NUMBER OF AGE GROUPS FOR WHICH
STATISTICAL TABLES ARE TO BE LISTED - 3

ENTER TEST AGES OF GROUPS TO BE VIEWED - 1 28 90
```

Figure 9. (Sheet 8 of 27)

PROJECT: RICHARD B RUSSELL
CONTRACT: DACW78-21-C0084
F'C: 2000. ": 1.282 MAX SIZE AGGR: 6.00

MIX: TOT12
DESIGN AGE: 90-DAY
W/C: 0.67

BATCH STATISTICS

MIX DATA YR	MO	DA	SAMPLE NUMBER	SEQUENCE NUMBER	CUMULATIVE AVERAGES W/C	SLUMP (IN)	AIR (%)
79	3	19	1	1	0.30	2.00	6.5
79	4	10	55	2	0.48	2.38	6.8
79	4	17	68	3	0.48	2.42	6.1
79	4	18	76	4	0.48	2.38	6.0
79	4	19	99	5	0.48	2.36	6.8
79	4	19	107	6	0.48	2.13	5.5
79	4	20	115	7	0.48	2.04	5.3
79	4	30	146	8	0.48	2.03	5.5
79	5	1	154	9	0.48	2.08	5.4
79	5	2	178	10	0.48	2.10	5.4
79	5	4	202	11	0.48	2.09	5.4
79	5	14	227	12	0.48	2.08	5.3
79	5	16	242	13	0.48	2.16	5.3
79	5	16	250	14	0.48	2.14	5.3
79	5	18	274	15	0.48	2.15	5.4
79	5	18	282	16	0.48	2.13	5.5
79	5	19	298	17	0.48	2.07	5.4
79	5	23	338	18	0.48	2.13	5.5
79	5	23	340	19	0.48	2.12	5.5
79	5	25	364	20	0.48	2.09	5.4
79	5	29	372	21	0.48	2.12	5.4
79	5	30	388	22	0.48	2.09	5.4
79	6	6	458	23	0.48	2.08	5.4
79	6	6	466	24	0.48	2.11	5.5
79	6	8	498	25	0.48	2.14	5.4
79	6	11	522	26	0.48	2.15	5.4
79	6	13	554	27	0.48	2.18	5.4
79	6	14	570	28	0.48	2.17	5.4
79	6	16	600	29	0.48	2.19	5.4
79	6	18	616	30	0.48	2.18	5.4

Figure 9. (Sheet 9 of 27)

U.S. ARMY CORPS OF ENGINEERS
EVALUATION OF CONCRETE STRENGTH DATA

PAGE: 6
DATE:02/24/83
TIME: 16:38

PROJECT: RICHARD B RUSSELL
CONTRACT: DACW78-21-C0084
F'C: 2000. T: 1.282 MAX SIZE AGGR: 6.00

MIX: TOT12
DESIGN AGE: 90-DAY
W/C: 0.67

REPORT FOR 1 DAY STRENGTHS

SAMPLE NUMBER	2CYL AVE	CUM AVE	L-S AVE	RANGE ACT	RANGE AVE	RANGE L-10	COEF OF VAR ACT	COEF OF VAR VU	COEF OF VAR VAR	STD DEV
	PSI	PSI	PSI	PSI	PSI	PSI	%	%	%	PSI
1	267	267	****	4	4	****	1.3	1.3	0.	0
55	265	266	****	****	4	****	****	****	0.5	1
68	327	286	****	4	4	****	1.2	1.2	12.3	35
76	305	291	****	7	5	****	2.1	1.5	10.4	30
99	336	300	300	36	13	****	10.6	3.8	11.0	33
107	380	313	323	18	14	****	5.1	3.9	14.1	44
115	358	320	341	7	13	****	1.9	3.5	13.6	44
146	361	323	346	7	12	****	1.9	3.2	12.9	42
154	622	357	409	0	10	****	0.	2.6	30.0	107
178	635	384	469	4	10	****	0.9	2.2	34.8	134
202	375	384	488	0	9	9	0.	2.0	33.1	127
227	591	401	515	36	11	12	7.7	2.5	33.7	135
242	430	403	530	11	11	13	2.4	2.4	32.1	130
250	531	412	512	29	12	15	6.2	2.7	31.3	129
274	488	417	483	28	14	14	5.9	2.9	30.2	126
282	470	421	502	14	14	14	3.0	2.9	29.1	122
298	588	430	501	7	13	14	1.4	2.7	29.1	125
332	536	436	522	10	13	14	2.0	2.6	28.4	124
340	511	440	519	18	13	16	3.6	2.7	27.6	122
364	420	439	505	8	13	16	1.6	2.6	27.0	119
372	422	438	495	10	13	17	2.0	2.6	26.4	116
380	533	443	484	3	12	14	0.6	2.5	25.9	115
458	377	440	452	11	12	14	2.2	2.5	25.6	113
466	345	436	419	10	12	12	2.0	2.5	25.7	112
498	373	433	410	10	12	10	2.0	2.5	25.6	110
522	460	434	417	0	12	9	0.	2.4	24.9	108
554	416	434	394	17	12	10	3.5	2.4	24.6	106
570	550	438	429	24	12	11	4.9	2.5	24.3	107
600	402	437	440	3	12	10	0.6	2.4	24.8	105
616	658	444	497	14	12	10	2.8	2.4	24.9	111

REQUIRED AVERAGE STRENGTH FOR ABOVE DATA = 178. PSI

Figure 9. (Sheet 10 of 27)

U.S. ARMY CORPS OF ENGINEERS
EVALUATION OF CONCRETE STRENGTH DATA

PAGE: 7
DATE:02/24/83
TIME: 16:38

PROJECT: RICHARD B RUSSELL
CONTRACT: DACW78-21-C0084
F'C: 2000. T: 1.282 MAX SIZE AGGR: 6.00

MIX: TOT:2
DESIGN AGE: 90-DAY
W/C: 0.67

REPORT FOR 28 DAY STRENGTHS

SAMPLE NUMBER	CUM AVE PSI	L-S AVE PSI	COEF VAR %	STD DEV PSI
1	999	*****	0.	0
55	1518	*****	48.3	733
68	1790	*****	39.2	701
76	1915	*****	32.6	625
99	1997	1997	28.6	571
107	2054	2266	25.8	530
115	2106	2341	23.9	502
146	2063	2226	23.3	481
154	2204	2436	28.0	618
178	2258	2518	26.9	607
202	2283	2557	25.5	582
227	2388	2782	27.8	663
242	2411	2968	26.5	640
260	2455	2907	25.9	637
274	2479	2922	25.0	621
282	2493	2965	24.2	602
298	2517	2828	23.5	591
332	2609	2784	22.9	575
340	2585	2648	22.3	559
364	2623	2656	21.8	550
372	2636	2674	21.3	539
388	2678	2791	21.9	564
458	2685	2858	21.3	551
466	2543	2688	22.6	576
498	2539	2603	22.2	564
522	2545	2582	21.8	554
554	2533	2331	21.6	546
570	2542	2345	21.2	538
600	2533	2483	20.9	531
616	2583	2681	21.3	546

Figure 9. (Sheet 11 of 27)

U.S. ARMY CORPS OF ENGINEERS
EVALUATION OF CONCRETE STRENGTH DATA

PAGE: 8
DATE: 02/24/83
TIME: 16:38

PROJECT: RICHARD B RUSSELL
CONTRACT: DACW78-21-C0084
F'C: 2000. T: 1.282 MAX SIZE AGGR: 6.00

FIX: TOT12
DESIGN AGE: 90-DAY
W/C: 0.67

REPORT FOR 90 DAY STRENGTHS

SAMPLE NUMBER	2CYL AVE	CUM AVE	L-5 AVE	RANGE ACT	RANGE AVE	RANGE L-10	COEF OF VAR ACT	COEF OF VAR WU	COEF OF VAR WAR	STD DEV
	PSI	PSI	PSI	PSI	PSI	PSI	%	%	%	PSI
1	1786	1786	****	0	0	****	0.	0.	0.	0
55	3316	2551	****	53	27	****	1.8	0.9	42.4	1082
68	3908	3003	****	318	124	****	9.4	3.7	36.5	1095
76	3891	3225	****	107	120	****	2.9	3.3	30.9	998
99	3714	3323	3323	283	152	****	7.6	4.1	26.8	892
107	3767	3397	3719	****	152	****	****	4.0	24.1	818
115	3926	3472	3841	106	146	****	2.7	3.7	22.3	773
146	3183	3436	3696	36	129	****	0.9	3.3	21.0	723
154	4943	3604	3906	169	133	****	3.9	3.3	23.4	842
178	4016	3645	3967	177	138	****	4.3	3.3	22.1	805
202	4342	3708	4082	159	140	140	3.8	3.3	21.4	792
227	5447	3853	4386	177	143	158	4.1	3.3	23.5	906
242	4041	3867	4567	725	192	285	16.6	4.4	22.5	889
250	4501	3913	4489	159	189	209	3.6	4.3	21.8	852
274	4351	3942	4536	141	186	212	3.2	4.2	21.0	820
282	4200	3958	4508	88	179	193	2.0	4.0	20.3	804
298	4704	4002	4369	354	190	218	7.8	4.2	20.0	799
332	3873	3996	4326	177	189	232	3.9	4.2	19.4	776
340	3776	3983	4181	53	182	221	1.2	4.0	19.0	755
364	3856	3977	4082	177	182	221	3.9	4.0	18.5	736
372	3873	3972	4016	212	183	226	4.7	4.1	18.1	717
380	6111	4024	4097	283	188	237	6.2	4.1	18.4	741
458	4156	4029	4154	707	211	235	15.6	4.7	18.0	726
466	2865	3981	3972	212	211	240	4.7	4.7	18.8	747
498	3555	3964	3912	177	210	244	4.0	4.7	18.6	737
522	4085	3968	3954	36	203	239	0.8	4.5	18.2	722
554	3431	3948	3818	141	201	218	3.2	4.6	18.1	716
570	4722	3976	3731	283	204	228	6.3	4.5	18.0	717
600	4050	3979	3968	0	196	223	0.	4.4	17.7	705
616	5226	4020	4303	195	196	225	4.3	4.3	18.1	729

REQUIRED AVERAGE STRENGTH FOR ABOVE DATA = 2934. PSI

Figure 9. (Sheet 12 of 27)

```
DO YOU WISH TO PLOT DATA(Y OR N) - Y
DO YOU WANT REPLOT CABILITIES(Y OR N) - N
ARE AIR CONTENTS AND SLUMPS TO BE PLOTTED(Y OR N) - Y
```

Figure 9. (Sheet 13 of 27)

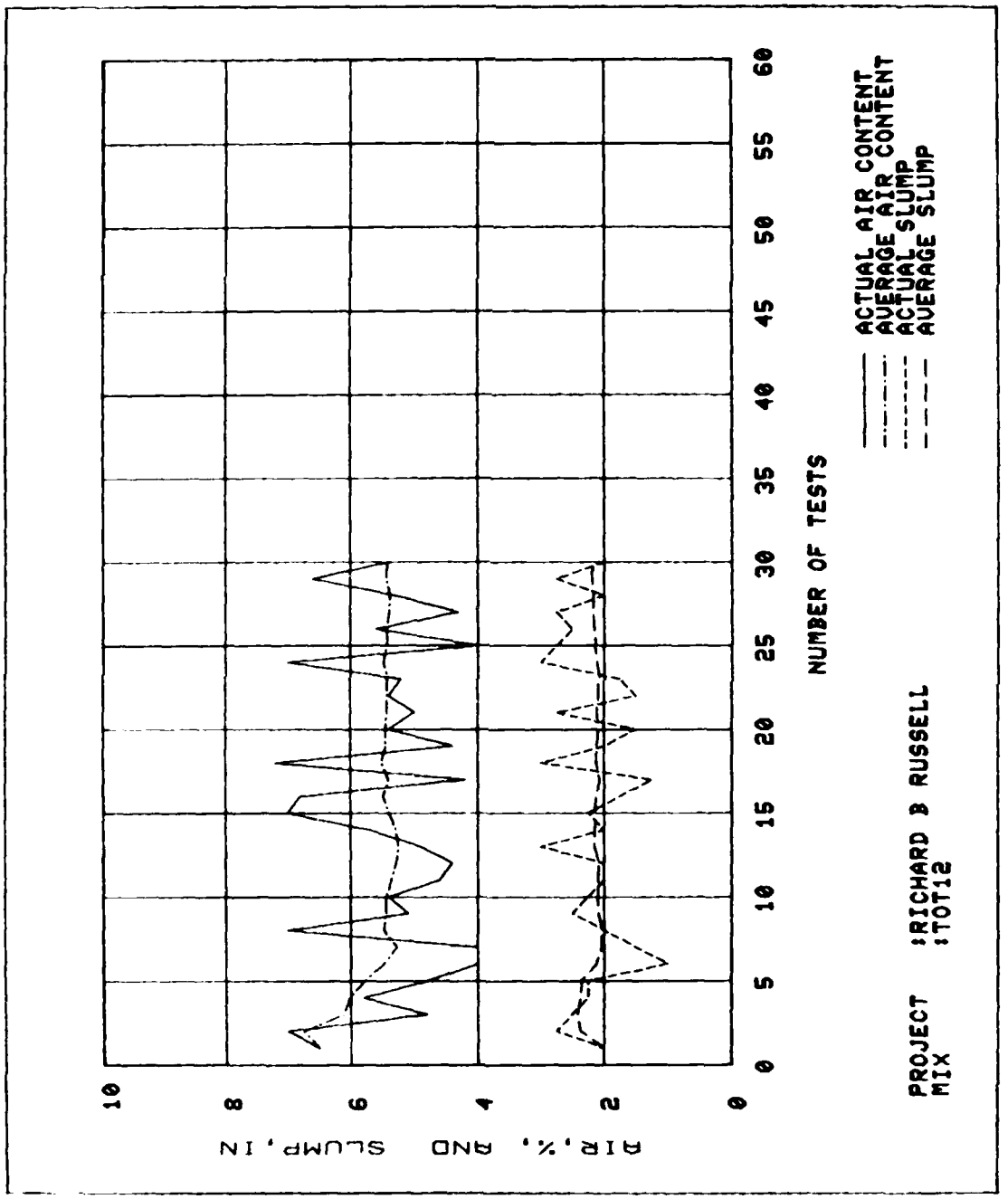

Figure 9. (Sheet 14 of 27)

```
DO YOU WISH TO PLOT PREDICTED STRENGTHS(Y OR N) - Y
```

Figure 9. (Sheet 15 of 27)

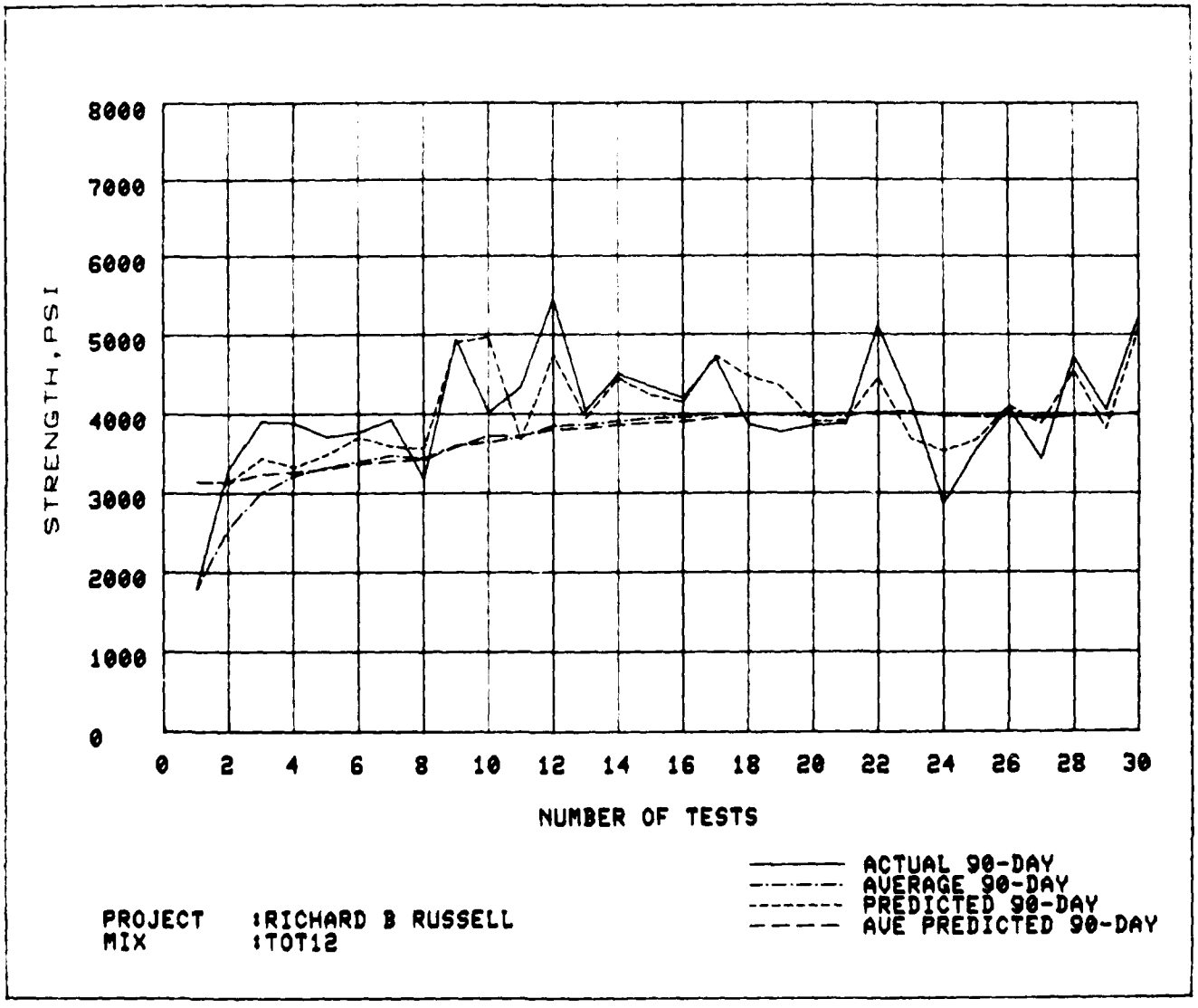

Figure 9. (Sheet 16 of 27)

```
ENTER NUMBER OF AGE GROUPS FOR WHICH
STATISTICAL TABLES ARE TO BE PLOTTED - 3

ENTER TEST AGES OF GROUPS TO BE VIEWED - 1 28 90
```

Figure 9. (Sheet 17 of 27)

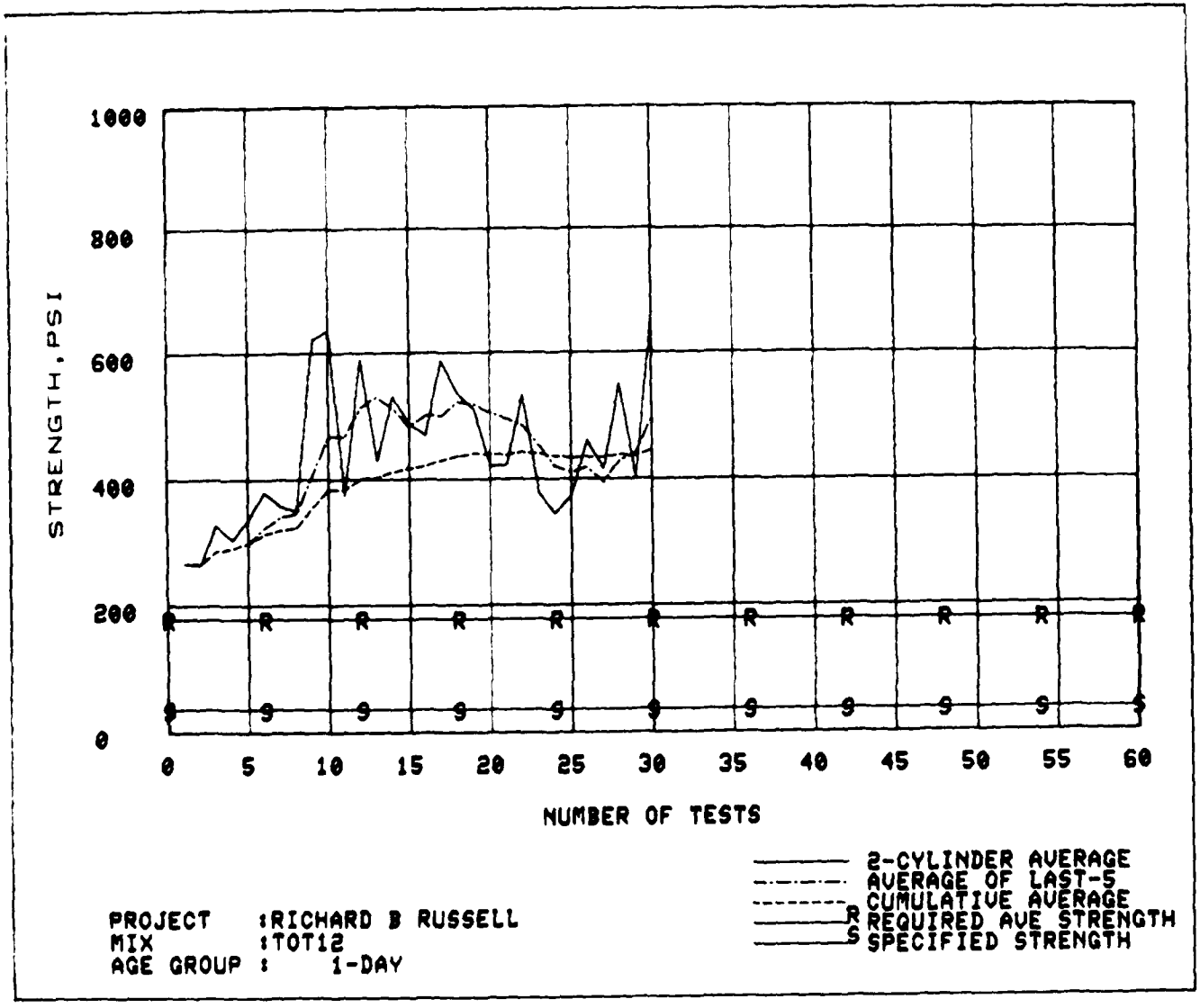

Figure 9. (Sheet 18 of 27)

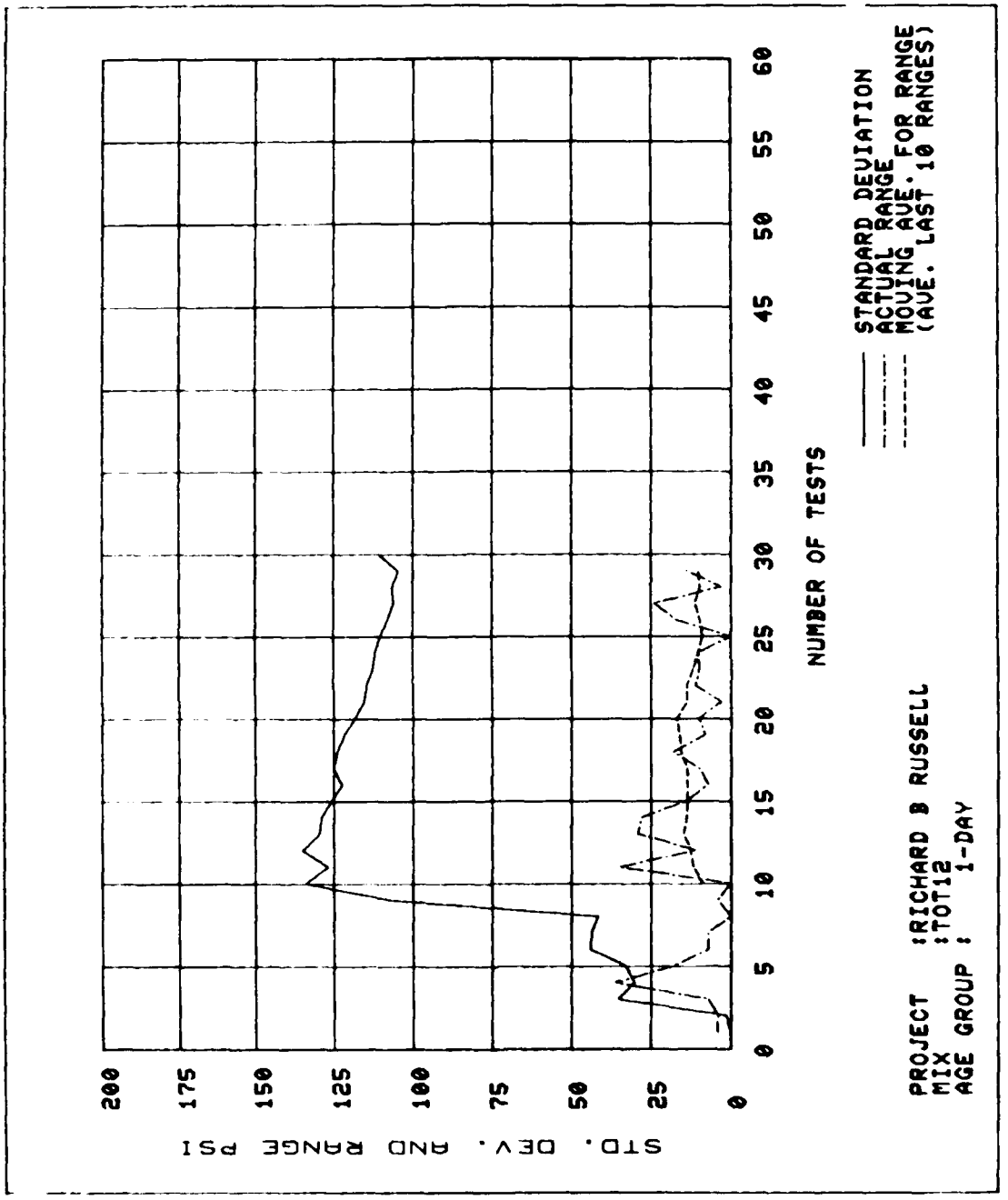

Figure 9. (Sheet 19 of 27)

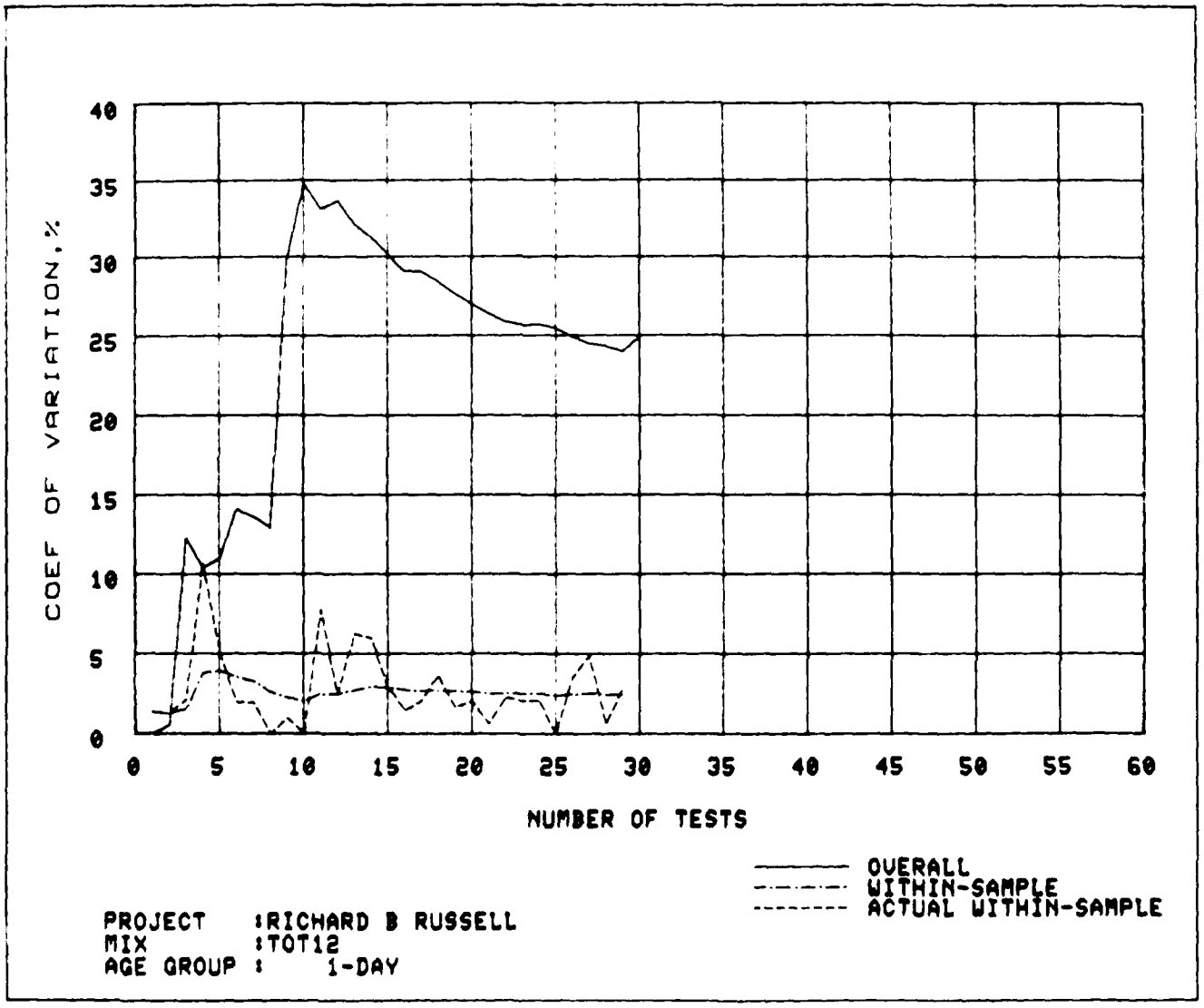

Figure 9. (Sheet 20 of 27)

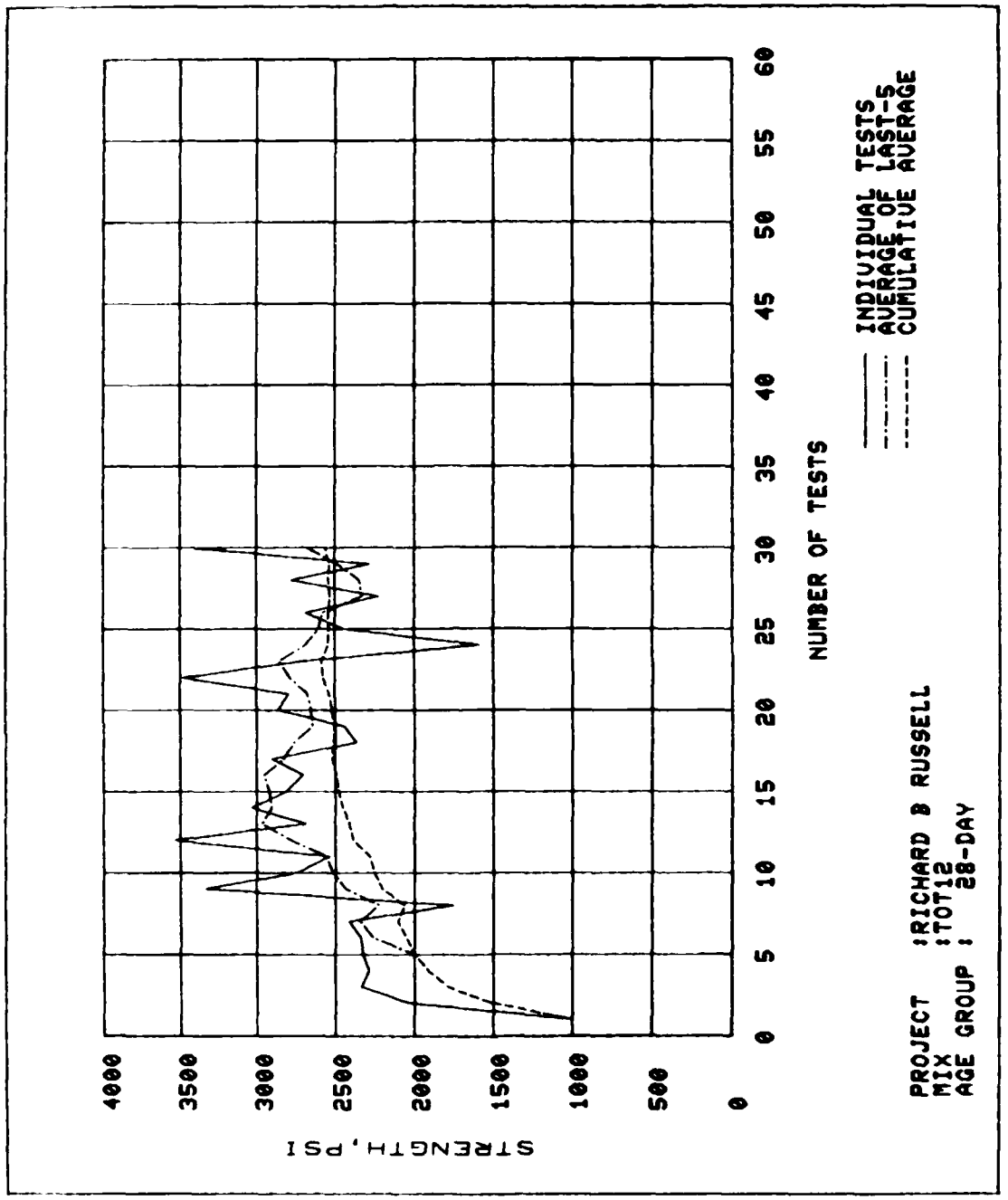

Figure 9. (Sheet 21 of 27)

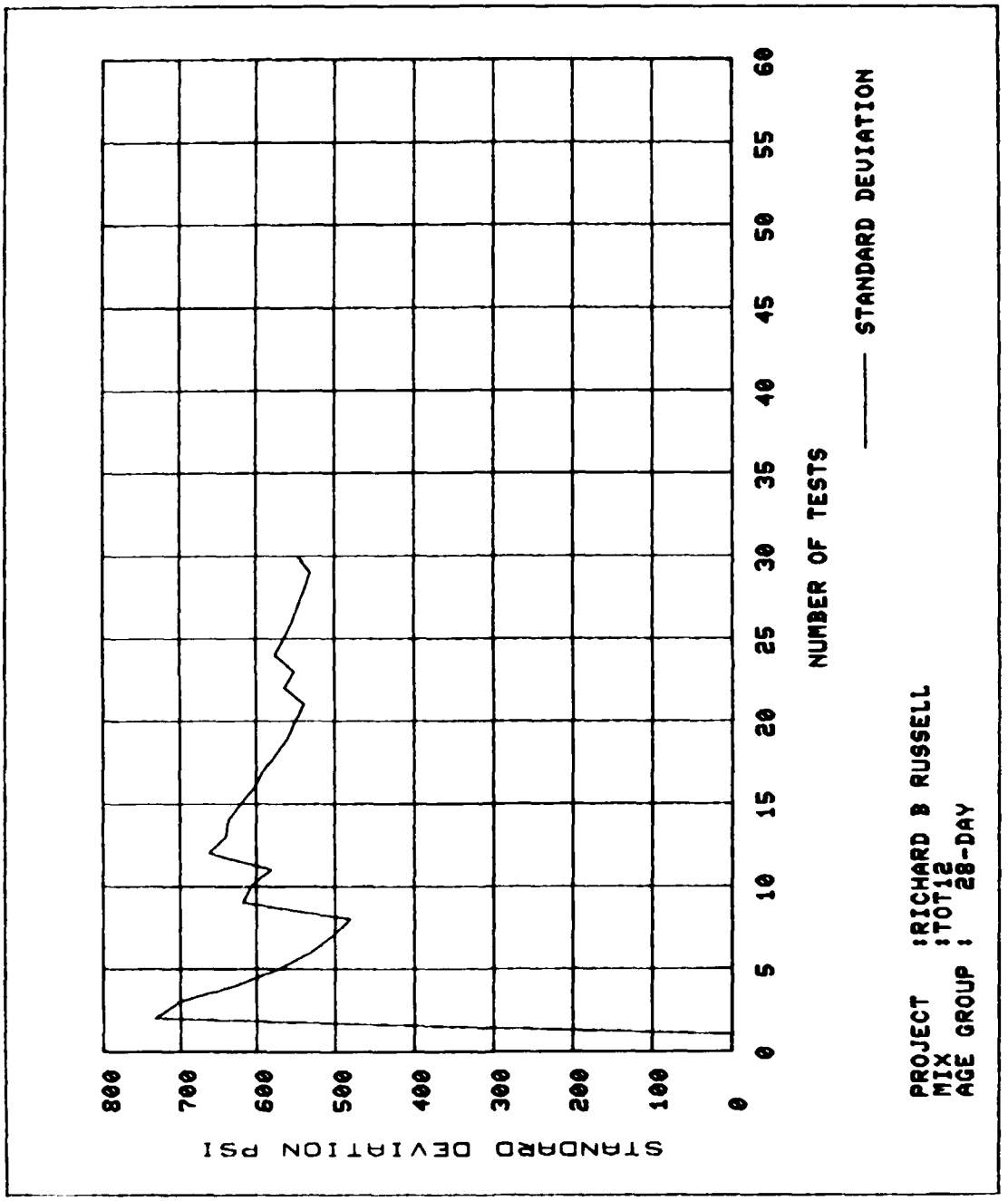

Figure 9. (Sheet 22 of 27)

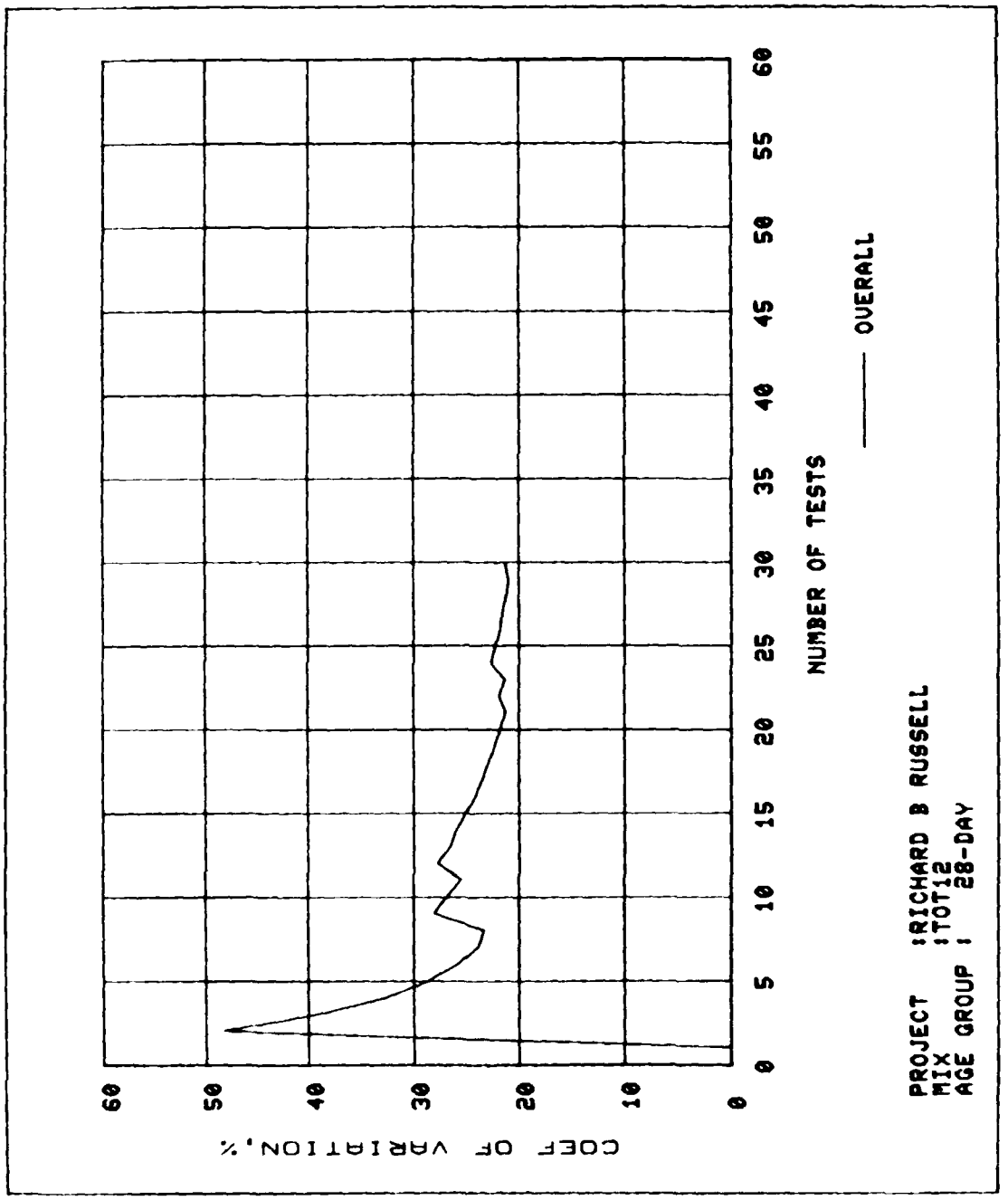

Figure 9. (Sheet 23 of 27)

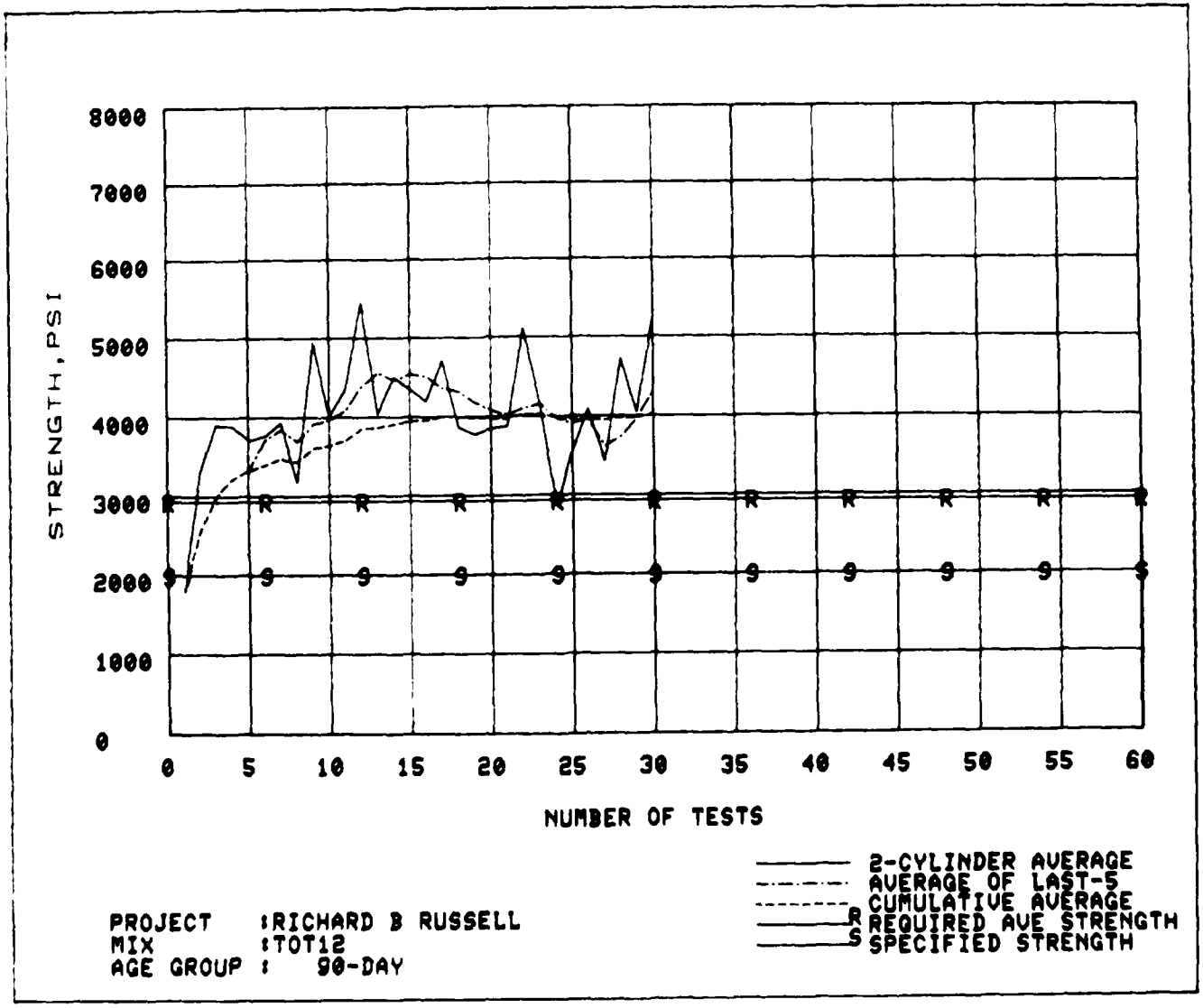

Figure 9. (Sheet 24 of 27)

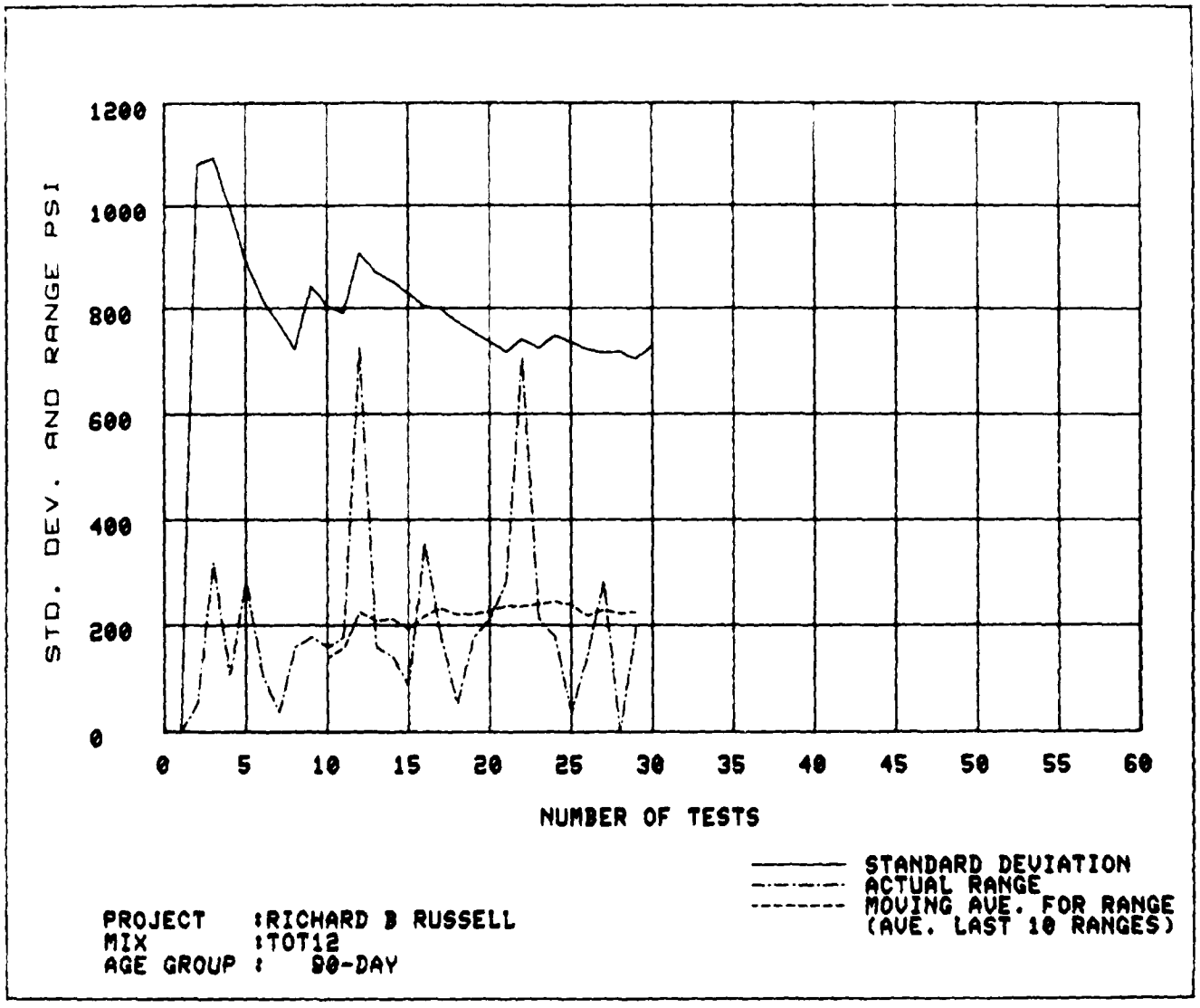

Figure 9. (Sheet 25 of 27)

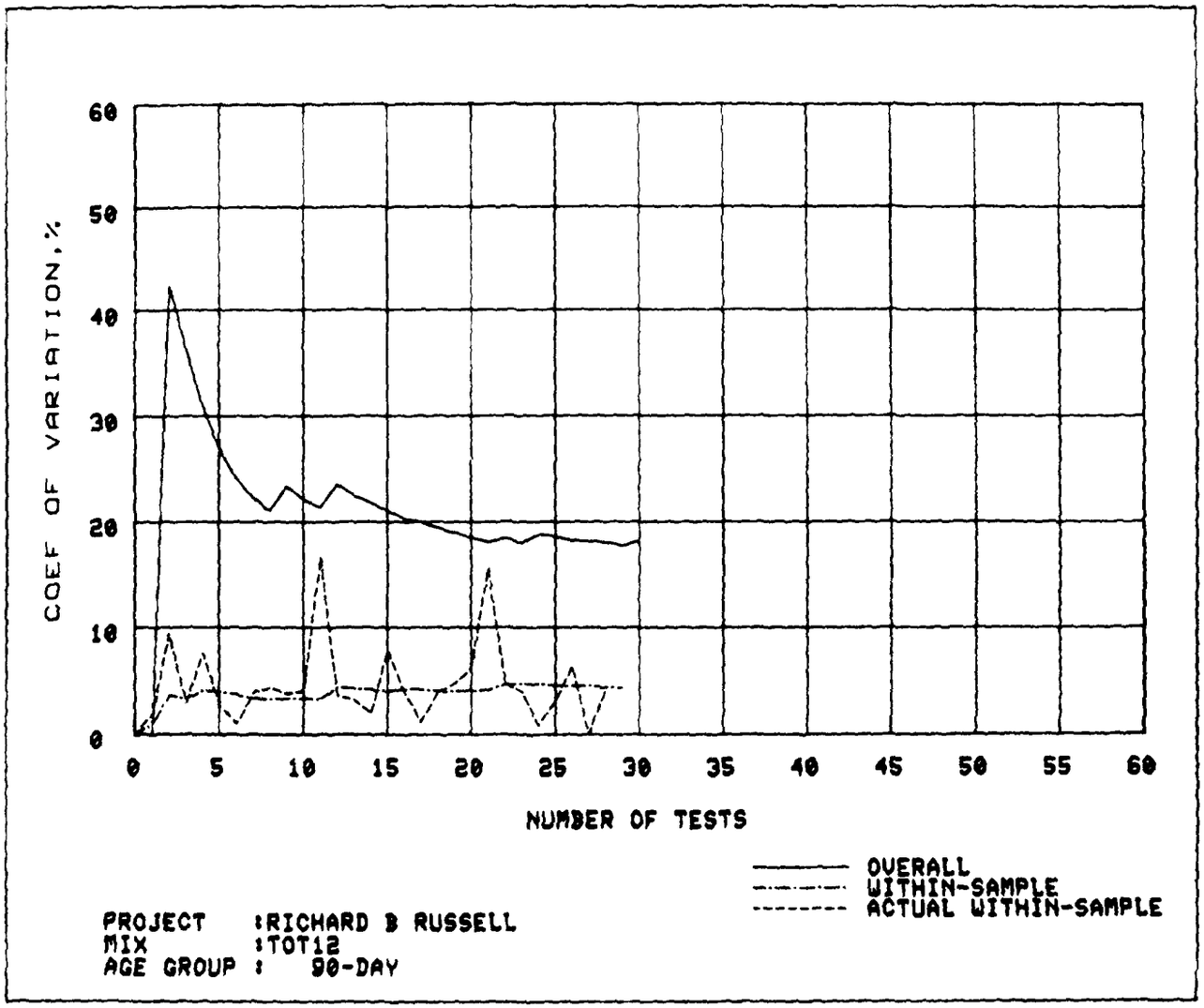

Figure 9. (Sheet 26 of 27)

```
DO YOU WISH TO RETURN TO TABLE OPTION(Y OR N) - N
DO YOU WISH TO RETURN TO PLOT OPTION(Y OR N) - N
IS RESTART FILE TO BE GENERATED(Y OR N) - Y
ENTER NAME OF OUTPUT FILE - F2
DO YOU WISH TO MAKE ANOTHER RUN(Y OR N) - N
*
```


Figure 9. (Sheet 27 of 27)

For WES or MACON systems:

```
*RUN WESLIB/CORPS/X0064,R
```

For BOEING system:

```
C>OLD,CORPS/UN=CECELB
C>CALL,CORPS,X0064
```

```
ENTER DEVICE SPEED(30 OR 120) - 120

DO YOU WISH TO ENTER DATA FROM TERMINAL(Y OR N) - N

ENTER NAME OF INPUT FILE - F2

IS INPUT DATA FROM A RESTART FILE(Y OR N) - Y

DO YOU WISH TO ANALYZE FIELD DATA(Y OR N) - Y

IS STRUCTURAL CONCRETE TO BE ANALYZED(Y OR N) - N

ENTER SLOPE,Y-INTERCEPT, AND NO. POINTS
FOR LABORATORY REGRESSION CURVE - 4.953 1022 30

ENTER UNITS FOR SLUMP(A2),STRENGTH(A3) AND TEMPERATURE(A1) - IN PSI F

ENTER NUMBER OF COPIES OF OUTPUT TO BE MADE - 3

DO YOU WISH TO LIST TABLES(Y OR N) - Y

DO YOU WISH TO LIST SUMMARY TABLE(Y OR N) - Y
```


Figure 10. Example showing a step-by-step execution of program using a restart file that contains field test results (Sheet 1 of 18)

U.S. ARMY CORPS OF ENGINEERS
EVALUATION OF CONCRETE STRENGTH DATA

PAGE: 1
DATE:02/24/83
TIME: 16:56

PROJECT: RICHARD B RUSSELL
CONTRACT: DACW78-21-C0084
F'C: 2000. T: 1.282 MAX SIZE AGGR: 6.00

MIX: TOT12
DESIGN AGE: 90-DAY
W/C: 0.67

SUMMARY TABLE

AVERAGE WATER/CEMENT RATIO	=	0.
AVERAGE SLUMP, IN	=	2.52
AVERAGE AIR CONTENT,%	=	5.6
REQUIRED 1-DAY ACCELERATED STRENGTH,PSI	=	36.
REQUIRED AVERAGE 1-DAY ACCELERATED STRENGTH,PSI	=	169.
SPECIFIED STRENGTH FOR 90-DAY STRENGTHS,PSI	=	2000.
REQUIRED AVERAGE 90-DAY STRENGTH,PSI	=	3240.

AGE	NO. TEST	SUM OF TEST	SUM OF TESTS SQUARED	TEST AVERAGE	AVE. RANGE	COEF. VARIATION WITHIN SAMPLE	COEF. VARIATION WITHIN GROUP	STD DEV
		PSI	PSI**2	PSI	PSI	%	%	PSI
1	59	26998.	13020799.	458.	13.	2.6	23.4	107.
7	59	61253.	87559739.	1038.	*****	*******	25.2	262.
28	59	173103.	538896464.	2934.	*****	*******	24.7	724.
90	59	248606.	1091416720.	4214.	286.	6.8	20.6	870.
365	0	0.	0.	0.	*****	*******	0.	0.

LINEAR REGRESSION OF 1-DAY AND DESIGN AGE(90-DAY) LAB DATA

EQUATION FOR LAB DATA IS : Y(90-DAY) = 1822. + 4.953*X(1-DAY)
NO. OF POINTS ON CURVE IS : 30

Figure 10. (Sheet 2 of 18)

DO YOU WISH TO LIST PREDICTED STRENGTHS(Y OR N) - Y

Figure 10. (Sheet 3 of 18)

U.S. ARMY CORPS OF ENGINEERS
EVALUATION OF CONCRETE STRENGTH DATA

PAGE: 2
DATE: 02/24/83
TIME: 16:56

PROJECT: RICHARD B RUSSELL
CONTRACT: DACW78-21-C0084
F'C: 2000. T: 1.282 MAX SIZE AGGR: 6.00

MIX: TCT12
DESIGN AGE: 90-DAY
W/C: 0.67

PREDICTED STRENGTHS

N	STRENGTH				
	ACCELERATED 1-DAY (PSI)	PREDICTED 90-DAY (PSI)	ACTUAL 90-DAY (PSI)	DIFFERENCE 90-DAY (PSI)	DIFFERENCE 90-DAY (%)
1	267.	3144.	1786.	-1358.5	-76.1
2	265.	3135.	3316.	181.5	5.5
3	327.	3442.	3908.	466.4	11.9
4	305.	3333.	3891.	558.3	14.3
5	336.	3486.	3714.	227.8	6.1
6	380.	3704.	3767.	62.9	1.7
7	358.	3595.	3928.	330.8	8.4
8	351.	3561.	3183.	-377.5	-11.9
9	622.	4903.	4943.	40.2	0.8
10	636.	4967.	4015.	-952.8	-23.7
11	375.	3679.	4342.	662.6	15.3
12	581.	4749.	5447.	697.8	12.8
13	430.	3958.	4041.	89.2	2.2
14	531.	4452.	4501.	49.0	1.1
15	488.	4239.	4351.	111.9	2.6
16	470.	4150.	4200.	50.1	1.2
17	588.	4734.	4704.	-30.4	-0.6
18	536.	4477.	3873.	-603.8	-15.6
19	511.	4363.	3776.	-577.0	-15.3
20	420.	3902.	3856.	-46.3	-1.2
21	422.	3918.	3873.	-39.2	-1.0
22	533.	4462.	5111.	649.1	12.7
23	377.	3689.	4156.	466.7	11.2
24	345.	3531.	2865.	-665.8	-23.2
25	373.	3669.	3555.	-114.5	-3.2
26	460.	4100.	4085.	-15.4	-0.4
27	416.	3882.	3431.	-451.4	-13.2
28	550.	4546.	4722.	175.8	3.7
29	402.	3813.	4050.	236.9	5.8
30	658.	5081.	5226.	144.9	2.8

Figure 10. (Sheet 4 of 18)

U.S. ARMY CORPS OF ENGINEERS
EVALUATION OF CONCRETE STRENGTH DATA

PAGE: 3
DATE: 02/24/83
TIME: 16:56

PROJECT: RICHARD B RUSSELL
CONTRACT: DACW28-21-C0084
F'C: 2000. T: 1.282 MAX SIZE AGGR: 6.00

MIX: TOT12
DESIGN AGE: 90-DAY
W/C: 0.67

PREDICTED STRENGTHS

N	STRENGTH				
	ACCELERATED 1-DAY (PSI)	PREDICTED 90-DAY (PSI)	ACTUAL 90-DAY (PSI)	DIFFERENCE 90-DAY (PSI)	DIFFERENCE 90-DAY (%)
31	367.	3640.	1786.	-1853.8	-103.8
32	365.	3630.	3371.	-258.8	-7.7
33	337.	3491.	4413.	921.8	20.9
34	306.	3330.	3896.	565.8	14.5
35	337.	3489.	3714.	225.3	6.1
36	380.	3704.	3767.	62.9	1.7
37	368.	3595.	3926.	330.8	8.4
38	356.	3685.	3233.	-352.3	-10.9
39	633.	4957.	5448.	490.8	9.0
40	635.	4967.	4520.	-447.7	-9.9
41	375.	3679.	5447.	1767.6	32.5
42	591.	4747.	5447.	699.8	12.8
43	536.	4472.	4591.	118.6	2.6
44	536.	4474.	5556.	1081.2	19.5
45	539.	4492.	5456.	963.8	17.7
46	570.	4645.	5256.	610.3	11.6
47	588.	4734.	5709.	974.6	17.1
48	541.	4502.	3873.	-628.6	-16.2
49	517.	4380.	3781.	-599.2	-15.8
50	586.	4426.	3881.	-583.8	-14.8
51	527.	4432.	3873.	-559.2	-14.4
52	533.	4462.	5661.	1199.1	21.2
53	377.	3689.	4656.	966.7	20.8
54	360.	3566.	3865.	309.4	8.0
56	373.	3669.	3610.	-60.0	-1.7
66	560.	4596.	5085.	489.3	9.6
57	521.	4403.	3431.	-972.0	-28.3
58	561.	4549.	5722.	1172.9	20.5
59	502.	4306.	5050.	744.1	14.7
AVERAGE	468.	4089.	4214.	********	*********
STD ERROR OF EST.	**********	**********	*********	666.2	21.2

Figure 10. (Sheet 5 of 18)

DO YOU WISH TO LIST INPUT DATA(Y OR N) - Y

Figure 10. (Sheet 6 of 18)

U.S. ARMY CORPS OF ENGINEERS
EVALUATION OF CONCRETE STRENGTH DATA

DATE:02/24/83
TIME: 16:56

PROJECT: RICHARD B RUSSELL
CONTRACT: DACW78-81-C0084
F'C: 2000. T: 1.282 MAX SIZE AGGR: 6.00

MIX: TCT12
DESIGN AGE: 90-DAY
W/C: 0.67

BATCH INPUT

MIX DATE							TEMP F		
YR	MO	DA	SAMPLE NUMBER	W/C	SLUMP (IN)	AIR (%)	AIR	CONC	REMARKS
**	**	**	RESTART	****	****	***	****	****	
79	4	19	1	****	3.00	6.5	****	67.	G-03-33A
79	5	10	55	****	3.75	7.0	****	53.	G-05-33C
79	5	17	68	****	3.50	6.8	****	55.	G-03-33A
79	5	18	76	****	3.35	5.8	****	55.	G-03-33A
79	5	19	99	****	3.35	5.8	****	65.	G-06-35
79	5	19	107	****	1.00	5.0	****	50.	G-06-35
79	5	30	115	****	1.50	5.0	****	55.	G-06-35
79	5	30	156	****	3.00	7.0	****	59.	G-05-33
79	5	1	155	****	3.50	5.1	****	53.	G-05-33
79	5	3	178	****	3.35	5.5	****	50.	G-03-33
79	5	5	303	****	3.00	5.6	****	55.	G-06-33
79	5	15	337	****	3.00	5.5	****	55.	G-03-33
79	5	16	353	****	3.00	5.9	****	56.	G-06-31
79	5	16	350	****	3.00	5.7	****	59.	G-05-31
79	5	18	375	****	3.35	7.0	****	****	G-03-31
79	5	18	383	****	1.75	6.8	****	55.	G-03-31
79	5	19	398	****	1.35	6.3	****	50.	G-03-33
79	5	33	333	****	3.00	7.3	****	63.	G-06-33
79	5	33	350	****	3.00	5.5	****	50.	G-06-31
79	5	35	365	****	1.50	5.5	****	53.	G-05-35
79	5	39	373	****	3.75	6.0	****	58.	G-05-30
79	6	30	380	****	1.50	5.5	****	50.	G-05-30
79	6	6	558	****	1.75	5.3	****	50.	G-03-33
79	6	6	566	****	3.00	7.0	****	****	G-03-33
79	6	8	598	****	3.75	5.0	****	53.	G-05-33
79	6	11	533	****	3.50	5.6	****	56.	G-05-19
79	6	13	555	****	3.75	5.3	****	50.	G-01-30
79	6	15	570	****	3.00	5.3	****	38.	G-06-31
79	6	15	600	****	3.75	6.6	****	53.	G-03-19

Figure 10. (Sheet 7 of 18)

U.S. ARMY CORPS OF ENGINEERS
EVALUATION OF CONCRETE STRENGTH DATA

PAGE: 5
DATE:02/24/83
TIME: 16:56

PROJECT: RICHARD B RUSSELL
CONTRACT: DACW78-21-C0084
F'C: 2000. T: 1.282 MAX SIZE AGGR: 6.00

MIX: TOT12
DESIGN AGE: 90-DAY
W/C: 0.67

TEST RESULTS

MIX DATE				CYLINDER STRENGTH (PSI)						
YR	MO	DA	SAMPLE NUMBER	1-D	1-D	7-D	28-D	90-D	90-D	365-D
**	**	**	RESTART	*****	*****	*****	*****	*****	*****	*****
79	4	19	1	365	369	595	999	1786	1786	*****
79	5	10	55	365	*****	796	3036	3363	3389	*****
79	5	17	68	339	335	770	3335	5067	3759	*****
79	5	18	76	301	308	893	3390	3837	3955	*****
79	5	19	99	355	318	858	3336	3573	3855	*****
79	5	19	107	371	389	831	3351	3767	*****	*****
79	5	30	115	381	356	833	3516	3979	3873	*****
79	5	30	156	367	355	679	1760	3185	3301	*****
79	5	1	155	633	633	1573	3336	6033	5863	*****
79	5	3	178	637	633	1331	3751	6103	3936	*****
79	5	5	303	376	376	1008	3538	5363	5631	*****
79	5	15	337	573	608	1309	3537	5636	6358	*****
79	5	16	353	535	535	1061	3688	3678	5503	*****
79	5	16	350	516	555	1036	3033	5680	5631	*****
79	5	18	376	575	60.	1185	3813	6380	5531	*****
79	5	18	383	577	56	1061	3706	6365	5166	*****
79	5	19	398	585	661	1116	3900	6881	5637	*****
79	5	33	333	531	551	1036	3370	3961	3785	*****
79	5	33	350	530	503	883	3650	3759	3803	*****
79	5	35	365	535	518	1619	3885	3955	3767	*****
79	5	39	373	517	537	1008	3795	3787	3979	*****
79	5	30	380	531	535	1586	3585	5353	5969	*****
79	6	6	558	371	383	1038	3706	3803	6509	*****
79	6	6	566	350	350	716	1593	3759	3971	*****
79	6	8	598	368	378	973	3550	3653	3566	*****
79	6	11	633	560	560	1008	3688	6103	6067	*****
79	6	13	665	507	535	956	3338	3360	3501	*****
79	6	16	670	538	663	1365	3776	6580	6863	*****
79	6	15	600	503	500	903	3381	6060	6060	*****

Figure 10. (Sheet 8 of 18)

```
ENTER NUMBER OF AGE GROUPS FOR WHICH
STATISTICAL TABLES ARE TO BE LISTED - 3

ENTEP TEST AGES OF GROUPS TO BE VIEWED - 1 28 90
```

Figure 10. (Sheet 9 of 18)

U.S. ARMY CORPS OF ENGINEERS
EVALUATION OF CONCRETE STRENGTH DATA

PAGE: 6
DATE:02/24/83
TIME: 16:56

PROJECT: RICHARD B RUSSELL
CONTRACT: DACW78-81-C0084
F'C: 2000. T: 1.282 MAX SIZE AGGR: 6.00

MIX: TOT:2
DESIGN AGE: 90-DAY
W/C: 0.67

BATCH STATISTICS

MIX DATA			SAMPLE NUMBER	SEQUENCE NUMBER	CUMULATIVE AVERAGES		
YR	MO	DA			W/C	SLUMP (IN)	AIR (%)
**	**	**	RESTART	1	0.	2.18	5.4
79	4	19	1	2	0.	2.21	5.5
79	5	10	55	3	0.	2.26	5.5
79	5	17	68	4	0.	2.30	5.5
79	5	18	76	5	0.	2.33	5.5
79	5	19	99	6	0.	2.36	5.5
79	5	19	107	7	0.	2.32	5.5
79	5	30	115	8	0.	2.30	5.5
79	5	30	166	9	0.	2.31	5.5
79	5	1	155	10	0.	2.34	5.5
79	5	3	178	11	0.	2.37	5.5
79	5	5	303	12	0.	2.39	5.5
79	5	15	337	13	0.	2.40	5.5
79	5	16	353	14	0.	2.41	5.5
79	5	16	350	15	0.	2.43	5.5
79	5	18	375	16	0.	2.45	5.6
79	5	18	383	17	0.	2.43	5.6
79	5	19	398	18	0.	2.41	5.6
79	5	33	333	19	0.	2.42	5.6
79	5	33	350	20	0.	2.43	5.6
79	5	35	365	21	0.	2.42	5.6
79	5	39	373	22	0.	2.44	5.6
79	5	30	380	23	0.	2.42	5.6
79	6	6	568	24	0.	2.41	5.6
79	6	6	586	25	0.	2.42	5.6
79	6	8	598	26	0.	2.45	5.6
79	6	11	533	27	0.	2.46	5.6
79	6	13	555	28	0.	2.49	5.6
79	6	15	570	29	0.	2.50	5.8
79	6	15	600	30	0.	2.52	5.6

Figure 10. (Sheet 10 of 18)

U.S. ARMY CORPS OF ENGINEERS
EVALUATION OF CONCRETE STRENGTH DATA

PAGE: 7
DATE: 02/24/83
TIME: 16:56

PROJECT: RICHARD B RUSSELL
CONTRACT: DACW28-21-C0084
F'C: 2000. T: 1.282 MAX SIZE AGGR: 6.00

FIX: TOT12
DESIGN AGE: 90-DAY
W/C: 0.67

REPORT FOR 1 DAY STRENGTHS

SAMPLE NUMBER	2CYL AVE	CUM AVE	L-S AVE	RANGE ACT	RANGE AVE	RANGE L-10	COEF OF VAR ACT	COEF OF VAR WW	COEF OF VAR VAR	STD DEV
	PSI	PSI	PSI	PSI	PSI	PSI	%	%	%	PSI
RESTART	****	444	497	****	12	10	****	2.4	24.9	111
1	367	441	479	4	12	28	0.8	2.4	24.8	110
55	365	439	468	****	12	28	****	****	24.7	109
68	337	436	426	4	12	28	0.8	2.3	24.9	108
76	305	432	406	7	11	27	1.4	2.3	25.2	109
99	337	429	342	37	12	30	7.6	2.5	25.3	109
107	380	428	345	18	12	31	3.7	2.6	25.1	107
115	358	426	343	8	12	32	1.2	2.5	25.0	107
156	356	424	347	2	12	30	0.4	2.5	24.9	106
155	633	430	413	0	12	28	0.	2.4	25.6	110
178	635	435	472	4	11	28	0.8	2.3	26.0	113
303	375	433	471	0	11	8	0.	2.3	25.8	112
337	591	437	518	36	12	11	7.1	2.4	25.9	113
353	636	439	564	0	11	11	0.	2.3	25.7	113
350	636	441	534	39	12	14	7.8	2.4	25.6	112
376	539	444	515	72	13	18	14.4	2.7	25.3	112
383	570	446	554	14	13	17	2.8	2.7	25.2	112
398	588	449	554	6	13	17	1.2	2.6	25.8	113
333	541	451	555	20	13	19	3.9	2.6	24.9	113
350	517	453	551	27	14	22	5.3	2.7	24.7	112
365	526	454	548	19	14	23	3.7	2.7	24.6	111
373	527	456	540	20	14	25	3.9	2.7	24.3	110
380	533	457	529	4	14	22	0.8	2.7	24.1	110
558	377	456	496	12	14	23	2.3	2.7	24.8	109
566	350	454	463	0	13	19	0.	2.6	24.1	109
598	373	452	432	10	13	13	2.0	2.6	24.1	109
533	560	454	439	0	13	12	0.	2.6	24.0	109
565	521	455	436	28	13	14	5.5	2.6	23.8	108
570	551	457	471	25	14	15	4.9	2.6	23.6	108
600	502	458	501	3	13	12	0.6	2.6	23.4	107

REQUIRED AVERAGE STRENGTH FOR ABOVE DATA = 189. PSI

Figure 10. (Sheet 11 of 18)

U.S. ARMY CORPS OF ENGINEERS
EVALUATION OF CONCRETE STRENGTH DATA

PAGE: 8
DATE:02/24/83
TIME: 16:56

PROJECT: RICHARD B RUSSELL
CONTRACT: DACW78-21-C0084
F'C: 2000. T: 1.282 MAX SIZE AGGR: 6.00

MIX: TOT12
DESIGN AGE: 90-DAY
W/C: 0.67

REPORT FOR 28 DAY STRENGTHS

SAMPLE NUMBER	CUM AVE PSI	L-S AVE PSI	COEF VAR %	STD DEV PSI
RESTART	2563	2681	21.3	546
1	2512	2343	24.1	606
55	2529	2505	23.9	604
68	2553	2616	23.9	610
76	2578	2838	24.0	618
99	2599	2819	23.9	622
107	2620	3289	23.9	626
115	2644	3385	24.0	634
156	2621	3070	24.6	642
155	2639	3069	24.4	644
178	2667	3142	24.7	659
303	2689	3180	24.7	665
337	2709	3184	24.7	670
353	2731	3570	24.8	678
350	2738	3509	24.5	672
375	2762	3522	24.7	683
383	2783	3555	24.8	690
398	2807	3428	25.0	702
333	2818	3564	24.8	699
360	2833	3668	24.7	699
365	2854	3678	24.8	707
373	2872	3698	24.8	713
380	2886	3633	24.7	718
658	2901	3708	24.6	715
666	2877	3309	25.4	730
598	2889	3246	25.2	729
633	2904	3824	25.1	730
655	2911	3175	24.9	726
670	2926	3189	24.9	728
600	2934	3547	24.7	724

Figure 10. (Sheet 12 of 18)

U.S. ARMY CORPS OF ENGINEERS
EVALUATION OF CONCRETE STRENGTH DATA

DATE:02/24/83
TIME: 16:56

PROJECT: RICHARD B RUSSELL
CONTRACT: DACW78-21-C0084
F'C: 2000. T: 1.282 MAX SIZE AGGR: 6.00

MIX: TOT12
DESIGN AGE: 90-DAY
W/C: 0.67

REPORT FOR 90 DAY STRENGTHS

SAMPLE NUMBER	2CYL AVE	CUM AVE	L-5 AVE	RANGE ACT	RANGE AVE	RANGE L-10	COEF OF VAR ACT	COEF OF VAR UU	COEF OF VAR UAR	STD DEV
	PSI	PSI	PSI	PSI	PSI	PSI	%	%	%	PSI
RESTART	****	4020	4303	****	196	225	****	4.3	18.1	729
1	1786	3948	3843	0	190	203	0.	4.3	20.8	821
55	3371	3930	3831	36	185	179	0.8	4.2	20.7	814
68	4413	3945	3769	1308	220	239	29.4	4.9	20.4	806
76	3896	3943	3738	118	217	229	2.7	4.9	20.1	793
99	3714	3937	3436	282	219	240	6.4	4.9	19.9	783
107	3767	3932	3832	****	219	240	****	4.9	19.6	772
115	3926	3932	3943	106	216	247	2.4	4.9	19.4	761
156	3233	3913	3707	136	213	246	3.1	4.8	19.4	759
156	5448	3953	4018	830	230	301	18.6	5.2	19.9	789
178	4520	3967	4179	1167	255	418	26.1	5.7	19.8	783
303	5447	4003	4515	168	252	415	3.7	5.6	20.2	807
337	5447	4037	4819	177	251	433	3.9	5.5	20.5	828
353	4591	4050	5090	1825	289	612	39.9	6.3	20.3	822
350	5566	4085	5118	49	283	486	1.1	6.1	20.7	844
375	5456	4115	5299	151	280	489	3.3	6.0	20.9	859
383	5256	4140	5281	199	278	481	4.3	6.0	20.9	866
398	5700	4173	5313	344	280	506	7.3	5.9	21.2	886
333	3873	4167	5170	176	278	509	3.7	5.9	21.1	878
350	3781	4159	4815	44	273	430	0.9	5.8	20.9	871
365	3861	4153	4496	188	271	332	4.0	5.8	20.8	863
373	3873	4148	4219	212	270	337	4.5	5.8	20.6	855
380	5661	4177	4210	616	277	380	13.1	5.9	20.9	872
558	4656	4186	4366	1706	305	369	36.1	6.5	20.7	886
566	3865	4180	4383	212	303	385	4.5	6.4	20.6	859
598	3610	4169	4333	87	299	378	1.8	6.4	20.5	855
633	5086	4186	4575	36	294	362	0.8	6.2	20.4	856
555	3431	4173	4129	141	291	342	3.0	6.2	20.5	854
570	5722	4199	4342	283	291	363	6.0	6.1	20.7	870
600	5060	4214	4578	0	286	348	0.	6.0	20.6	870

REQUIRED AVERAGE STRENGTH FOR ABOVE DATA = 3240. PSI

Figure 10. (Sheet 13 of 18)

```
DO YOU WISH TO PLOT DATA(Y OR N) - Y
DO YOU WANT REPLOT CABILITIES(Y OR N) - Y
ARE AIR CONTENTS AND SLUMPS TO BE PLOTTED(Y OR N) - N
DO YOU WISH TO PLOT PREDICTED STRENGTHS(Y OR N) - Y
```

Figure 10. (Sheet 14 of 18)

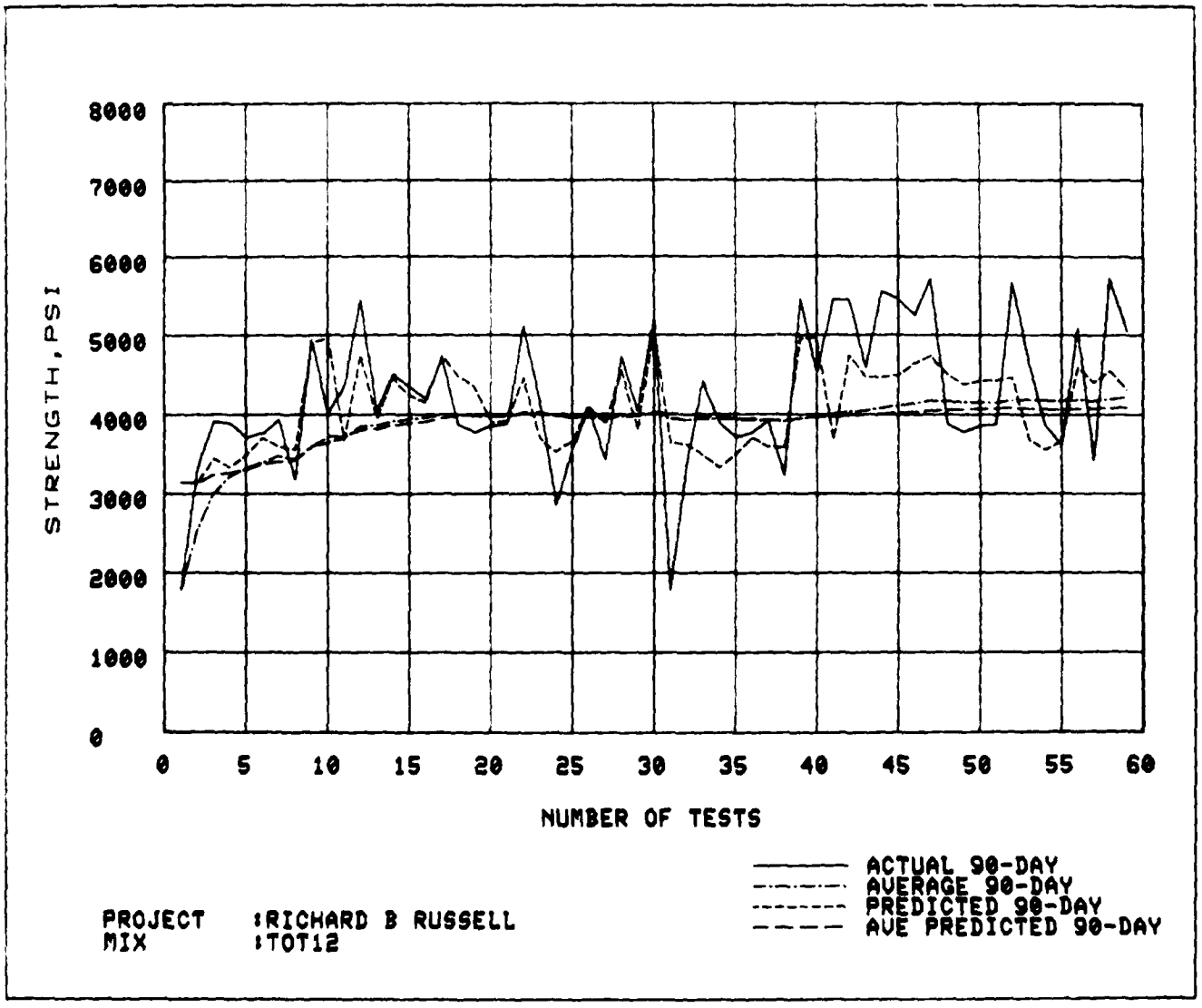

Figure 10. (Sheet 15 of 18)

```
DO YOU WANT TO REPLOT USING YOUR OWN SCALE(Y OR N) - Y
ENTER XMIN,XMAX,YMIN,YMAX - 30 60 3000 6000
```


Figure 10. (Sheet 16 of 18)

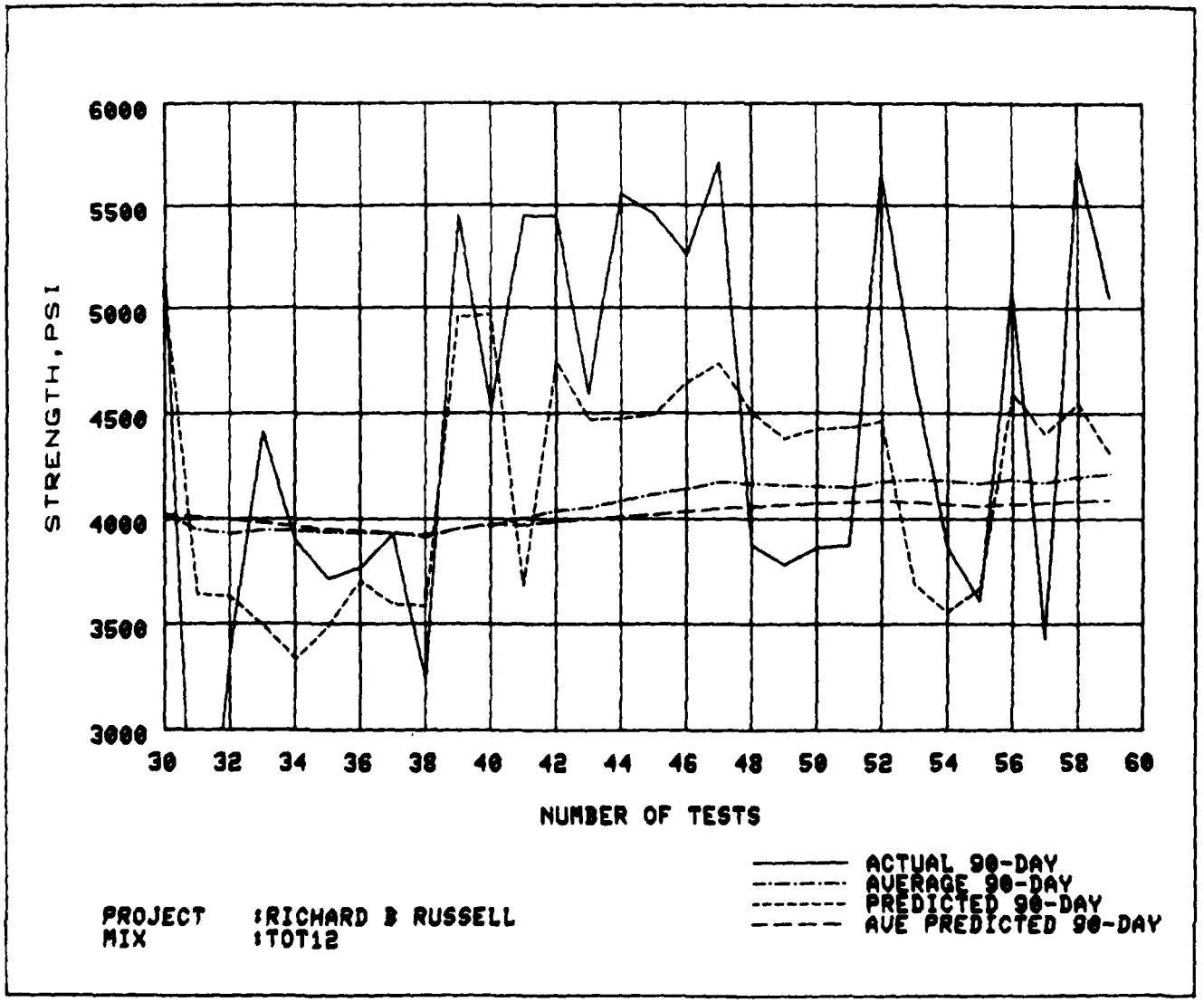

Figure 10. (Sheet 17 of 18)

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DO YOU WANT TO REPLOT USING YOUR OWN SCALE(Y OR N) - N

ENTER NUMBER OF AGE GROUPS FOR WHICH
STATISTICAL TABLES ARE TO BE PLOTTED - 0

DO YOU WISH TO RETURN TO TABLE OPTION(Y OR N) - N

DO YOU WISH TO RETURN TO PLOT OPTION(Y OR N) - N

IS RESTART FILE TO BE GENERATED(Y OR N) - N

DO YOU WISH TO MAKE ANOTHER RUN(Y OR N) - N

*
```


Figure 10. (Sheet 18 of 18)

PART VII: CONCLUDING STATEMENT

19. The program described in this report is the third-generation program for performing this general sort of analysis of Corps of Engineers concrete strength data. The previous programs were prepared by Lamond (1974) and Bradstreet and Hughes (1979).

20. Strength data used in the examples of this report were taken from test results of concrete used in Richard B. Russell Dam. A study of these results has been made by Ragan (1983). A discussion of this sort of work has been published by Lamond (1979).

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APPENDIX A

DERIVATION OF 95 PERCENT CONFIDENCE INTERVAL FOR THE MEAN RESPONSE OF THE DESIGN-AGE STRENGTH FOR A GIVEN ACCELERATED STRENGTH

Assumptions

(1) Confidence interval:

$$Ci = t\, S_{y \cdot x}$$

where Ci = 95 percent confidence interval

$S_{y \cdot x}$ = Standard error of estimate

t = t-distribution factor for 95 percent confidence interval, for n = 1 to 29 , t-distribution factor is 12.706, 4.303, 3.182, 2.776, 2.571, 2.447, 2.365, 2.306, 2.262, 2.228, 2.201, 2.179, 2.160, 2.145, 2.131, 2.120, 2.110, 2.101, 2.093, 2.086, 2.080, 2.074, 2.069, 2.064, 2.060, 2.056, 2.052, 2.048, and 2.045, respectively; for $n \geq 30$, t-distribution factor is 1.960.

n = Number of points on regression curve

(2) Standard error of estimate:

$$S_{y \cdot x} = \sqrt{\frac{n - 1}{n - 2}\left(\sigma_y^2 - b^2 \sigma_x\right)}$$ (See Appendix B for derivation)

where $S_{y \cdot x}$ = Standard error of estimate

b = Slope of regression curve

n = Number of points on regression curve

σ_x = Standard deviation of accelerated strengths

σ_y = Standard deviation of design-age strengths

(3) Standard deviation of accelerated strengths:

$$\sigma_x = \sqrt{\frac{\Sigma X_i^2 - \frac{(\Sigma X_i)^2}{n}}{n - 1}}$$

where n = Number of points on regression curve

σ_x = Standard deviation of accelerated strengths

X_i = An individual accelerated strength

(4) Standard deviation of design-age strengths:

$$\sigma_y = \sqrt{\frac{\Sigma Y_i^2 - \frac{(\Sigma Y_i)^2}{n}}{n-1}}$$

where n = Number of points on regression curve

σ_y = Standard deviation of design-age strengths

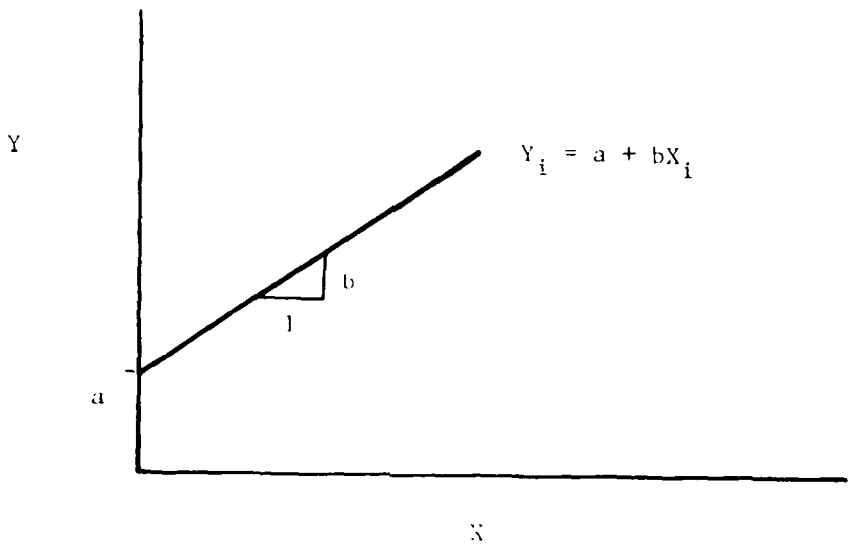
Y_i = An individual design-age strength

Derivation

Description of Operation	Resulting Equation
Entering confidence interval from (1) above	$Ci = t\, S_{y \cdot x}$
Substituting for '$S_{y \cdot x}$' from (2) above	$Ci = t\sqrt{\frac{n-1}{n-2}\left(\sigma_y^2 - b^2\sigma_x^2\right)}$
Substituting for 'σ_x' from (3) above and for 'σ_y' from (4) above	$Ci = t\sqrt{\frac{1}{n-2}\left(\Sigma Y_i^2 - \frac{(\Sigma Y_i)^2}{n} - b^2\left(\Sigma X_i^2 - \frac{(\Sigma X_i)^2}{n}\right)\right)}$

APPENDIX B

DERIVATION OF STANDARD ERROR OF ESTIMATE



Regression Curve

Assumptions

(1) Sum of squares of error:

$$SSE = \Sigma(Y_i - a - X_i)^2$$

where a = Y-intercept for regression curve

SSE = Sum of squares of errors

X_i = An individual accelerated strength

Y_i = An individual design-age strength

(2) Regression equation:

$$Y_i = a + bX_i \quad ; \quad a = \bar{Y} - b\bar{X}$$

where a = Y-intercept for regression curve

b = Slope of regression curve

X_i = An individual accelerated strength

$\bar{X}$ = Average accelerated strength

Y_i = An individual design-age strength

$\bar{Y}$ = Average design-age strength

(3) Slope of regression curve:

$$b = \frac{Y_i - \bar{Y}}{X_i - \bar{X}} \quad ; \quad (Y_i - \bar{Y}) = b(X_i - \bar{X})$$

where b = Slope of regression curve

X_i = An individual accelerated strength

$\bar{X}$ = Average accelerated strength

Y_i = An individual design-age strength

$\bar{Y}$ = Average design age strength

(4) Standard deviation of accelerated strengths:

$$\sigma_X = \sqrt{\frac{\Sigma(X_i - \bar{X})^2}{n - 1}} \quad ; \quad \Sigma(X_i - \bar{X})^2 = (n - 1)\sigma_X^2$$

where n = Number of points on regression curve

σ_X = Standard deviation of accelerated strengths

X_i = An individual accelerated strength

$\bar{X}$ = Average accelerated strength

(5) Standard deviation of design-age strengths:

$$\sigma_Y = \sqrt{\frac{\Sigma(Y_i - \bar{Y})^2}{n - 1}} \quad ; \quad \Sigma(Y_i - \bar{Y})^2 = (n - 1)\sigma_Y^2$$

where n = Number of points on regression curve

σ_Y = Standard deviation of design-age strength

Y_i = An individual design-age strength

$\bar{Y}$ = Average design-age strength

(6) Unbiased estimation $S^2_{y \cdot x}$ of σ^2 with $n - 2$ degrees of freedom (σ = standard deviation):

$$S^2_{y \cdot x} = \frac{SSE}{n - 2}$$

where n = Number of points on regression curve

$S_{y \cdot x}$ = Unbiased estimator of standard deviation

SSE = Sum of squares of errors

Derivation

Description of Operation	Resulting Equation
Entering equation for $S^2_{y \cdot x}$ from (6) above	$S^2_{y \cdot x} = \frac{SSE}{n - 2}$
Substituting for 'SSE' from (1) above	$S^2_{y \cdot x} = \frac{\Sigma(Y_i - a - X_i)^2}{n - 2}$
Substituting for 'a' from (2) above	$S^2_{y \cdot x} = \frac{\Sigma((Y_i - \bar{Y}) - b(X_i - \bar{X}))^2}{n - 2}$
Collecting terms	$S^2_{y \cdot x} = \frac{\Sigma((Y_i - \bar{Y})^2 - 2b(X_i - \bar{X})(Y_i - \bar{Y}) + b^2(X_i - \bar{X})^2)}{n - 2}$
Substituting for '$(Y_i - \bar{Y})$' from (3) above	$S^2_{y \cdot x} = \frac{\Sigma((Y_i - \bar{Y})^2 - b^2(X_i - \bar{X})^2)}{n - 2}$
Substituting for '$(X_i - \bar{X})^2$' from (4) above and for '$(Y_i - \bar{Y})^2$' from (5) above	$S^2_{y \cdot x} = \frac{(n - 1)(\sigma_y^2 - b^2(n - 1)\sigma_X^2)}{n - 2}$
Taking square root	$S_{y \cdot x} = \sqrt{\frac{(n - 1)}{(n - 2)}(\sigma_y^2 - b^2\sigma_x^2)}$